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ABSTRACT

The objectives of this study are to ensure that the resources at the disposal of the librarian are deployed in a manner which will effectively contribute to the purposes of the university. User behavior is explored in an attempt to solve the difficulties that arise in library planning and management, such as: (1) the relationship between length of loan period and "idle time," (2) the availability of popular books and (3) the relationship between library usage and academic achievement. Fundamentally related to all this in a university library is the whole area of students' problem-solving behavior. It is clear that the serious study of policy-making and the allocation of resources in a university library must range widely over problems of human behavior and educational research. Seen in this wider context it may be that the most useful contribution of this study is the way which, with further research, it may prove possible to quantitatively relate the day-to-day decisions of the librarian to the academic achievement of the university as a whole. This document previously announced as ED 044 153. (MF)

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SYSTEMS ANALYSIS OF A UNIVERSITY LIBRARY

Final Report on a Research Project

by

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and I. Woodburn

"PERMISSION TO REPRODUCE THIS COPYRIGHTED MATERIAL HAS BEEN GRANTED BY University of Lancaster

TO ERIC AND ORGANIZATIONS OPERATING UNDER AGREEMENTS WITH THE U.S. OFFICE OF EDUCATION FURTHER REPRODUCTION OUTSIDE THE ERIC SYSTEM REQUIRES PERMISSION OF THE COPYRIGHT OWNER."

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University of Lancaster Library

1970

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PREFACE

This report is the fourth in a series of papers which are published, at irregular intervals, to make available the results of research work carried out by members of the Library staff (see inside back cover for previous titles).

From January 1967 until June 1969 the Office for Scientific and Technical Information financed a research team within the Library; parts of its work have been reported elsewhere, but the present volume is a definitive account of the whole project for this period. Further work is being financed by the University.

A. Graham Mackenzie
Librarian

January, 1970

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CHAPTER 1: INTRODUCTION

The establishment of nine new universities in the 1960's provoked a highly stimulating re-examination of the nature, purpose and management of academic libraries. Long-established attitudes and methods were questioned, but although changes were made, the basic difficulty remained - a lack of objective information about the best ways of providing a library service in a university. The report of the UGC Committee on Libraries (the Parry Report (267)),which, in general, endorsed these changes, also stressed the need for research into all aspects of academic library provision.

The efficient exploitation of limited resources to provide as useful a library service as possible requires more than the traditional techniques of librarianship; cataloguing, classification, bibliography and similar skills are essential, but they do not tell one how many books to buy, how long to keep them, or how long the loan period should be. To answer these and a variety of other questions, an understanding is required of the likely consequences for the users of any given combination of managerial decisions concerning the allocation of resources, the deployment of labour, and the choice of operating practices. This understanding should be quantitative whenever possible: that is to say, the understanding should be sufficiently advanced to permit the making of measurements, estimates and predictions in numerical form.

Although a library provides a variety of services to its users, in the university context its major rôle, at any given point in time, is that of providing direct assistance to the problem-solving behaviour of its users. Every user has problems, in the intellectual and cognitive sense, and the library attempts to help in solving many of these. The complexity of deciding between the many possible library policies derives from the very wide variety of problem-solving activities in which the library becomes involved: users range, for example, from the researcher requiring obscure documents which are relevant to the development of theory in a new area to the undergraduate looking for a minimum-effort solution to an essay preparation problem. A rational policy for a university library implies that it should optimise its assistance to its users in the solution of their problems, within the limits of its resources; this can only be achieved if the relative importance of differing user problems can be assessed, if efficient methods of assistance can be determined, and if the likely effectiveness of help can be evaluated. A complete answer is clearly impossible to achieve, at least with present knowledge; nevertheless a progressive approach towards this ideal is feasible. This represents the essential motivation for research into library management problems.

Unfortunately academic libraries do not lend themselves easily to experimentation: it is not often practical to set up a variety of different library services, either simultaneously or successively; nor is there much scope for experimentally withdrawing library services. In brief, considerable justification is required for any experimental tampering with library services in vivo.

A suitable methodology for such an investigation is that of Operational Research - more specifically the development of mathematical models and computer simulations of various library sub-systems. The purpose of such a model or simulation is to form a suitable abstraction of reality, preserving the essential structure of the problems in such a way that analysis affords insight into both the original concrete situation and other similar situations. The manner in which these models and simulations are linked together will depend upon the particular management information which is required.

Since the University of Lancaster and its Library were both new (the first intake of students was in 1964), there has been considerable awareness of the problems of designing and

managing an effective library service: consequently in January 1967 a research project was established, with financial support from the Office for Scientific and Technical Information, to explore and analyse the underlying nature of the provision and use of library services, by identifying and describing - numerically whenever possible - what happens in a library. The reason for this work was that all managerial and planning decisions must be based on some decision-maker's perception of the situation and of the likely consequences of each particular decision; this perception will depend upon the decision-maker's experience, his attitudes and the information available to him, modified, perhaps, by the experiences, attitudes and information of those who advise him. The more detailed, the more precise and the more quantitative the information which can be made available, the better the resulting planning and managerial decisions are likely to be. This project, then, was concerned with exploring, analysing and describing the interactions which take place in the provision and use of library services, with the aim of providing an improved basis for decision-making in planning and management.

This report summarises the work done in the course of the project.

Mr. A. Graham Mackenzie, the University Librarian, was the Principal Investigator, and three other investigators were employed during the project:

Mr. Michael K. Buckland, a librarian, was seconded from his normal duties in the University Library to work full time for the duration of the project, January 1967 to June 1969.

Mr. Ian Woodburn, a systems engineer, was appointed as half-time Research Fellow and remained part of the team for the first two years, January 1967 to December 1968; his appointment was made jointly with that of half-time Lecturer in Optimization Techniques in the Department of Systems Engineering.

Dr. Anthony Hindle, Lecturer in the Department of Operational Research, acted as Consultant on a part-time basis in place of Mr. Woodburn during the period January to June 1969.

A number of clerical assistants were employed as and when required, notably Mrs. Romana Bell, Mrs. Waltraud Buckland, Mrs. P. Illingworth and Mr. Peter Ryan; in addition Mr. Mel Dobson, Mr. David Nash and Mr. A.J. Playle helped with computer programming. Most of the cost of the project was met by a grant and two continuation grants from the Office for Scientific and Technical Information: this essential assistance, and informal help from numerous others, both from within the University of Lancaster Library and from the libraries of the Universities of Manchester, Strathclyde and Sussex and elsewhere, are gratefully acknowledged.

Note: A more detailed account of the thinking which led to this project can be found in: A.G. Mackenzie. Systems analysis of a university library. Program: News of computers in British Libraries 2, (1), April 1968, 7-14.

CHAPTER 2: TECHNICAL PROCESSES: WORKFLOW AND LABOUR ALLOCATION

The work of creating models of aspects of library provision and use began with an examination of the flow of materials through the various processes which are necessary for the acquisition of books and other library material and their preparation for the shelves. This aspect of the library seemed to lend itself readily to mathematical modelling, and to have a great deal in common with industrial processes - an area where there is much more experience of such modelling.

From the decision that a given item ought to be included in the library's collections to the end-state of having the book on the shelf and cards in the catalogue, there is a series of consecutive operations through which work flows from one to the next. Many of these are very similar in structure: for example, books arrive for cataloguing, and such as are catalogued will move on to the next process. If the amount of labour allocated to cataloguing is inadequate for the work to be done, then the uncatalogued material will accumulate as arrears of cataloguing; if, however, the cataloguing capacity exceeds the amount of cataloguing coming in, then the backlog of cataloguing, if there is one, will be reduced and perhaps abolished. In fine, the number of books catalogued is primarily determined by the speed of cataloguing and by the number of man-hours available for cataloguing - always assuming that the work-capacity does not exceed the work-load within the cataloguing department.

For process i, let

x_i be the input rate (items per time period)

l_i be the labour allocated (man-hours per time period)

w_i be the workrate (items per man-hour)

p_i be the processing capacity (items per time period)

b_i be the backlog at the end of the time period (items)

d_i be the delay till arrears have been cleared and next incoming item can be processed, assuming a first-come, first-processed method of working (time periods)

y_i be output rate (items per time period)

Consider time period t: the processing capacity will be determined by the product of the workrate per manhour and the number of manhours assigned:

$$p_i(t) = l_i(t) \times w_i(t)$$

If sufficient work is available the work done will equal the processing capacity; otherwise as much work as is available will be completed. (The work available, of course, includes both incoming material and any backlog which may be left over from the end of the previous time period):

$$y_i(t) = p_i(t) \text{ if } b_i(t-1) + x_i(t) \geq p_i(t)$$

This backlog was also described in terms of the number of time periods of work it represented at the current processing capacity:

$$d_i(t) = b_i(t) \; / \; p_i(t)$$

Most of the technical processes of the library could be represented in this way with two exceptions: the bookseller and the binder. In each of these cases material being dealt with was subject to a wide range of delays. We therefore assumed a distribution of delays: for example, 4% of orders were supplied by booksellers in the first week after ordering, 10% in the second week after ordering, 10% in the third ... and so on. Accordingly one would expect to receive in any given week 4% of items ordered that week, 10% of those ordered the previous week, 10% of those ordered the week before that ... and so on. The binding delays were described similarly.

For process j, let

x_j be the input rate (items per time period)

y_j be the output rate (items per time period)

f(n) be the fraction of books supplied during the nth time period since the order was despatched to the bookseller.

$$y_j(t) = f(o) \times x_j(t) + f(1) \times x_j(t-1) + f(2) \times x_j(t-2) \ldots \text{ etc.}$$

$$= \sum_{n=0}^{n=\infty} f(n) \times x_j(t-n)$$

Having determined a method of representing the processes, the next stage was to link them together. The resulting flow diagram, based on the processes and organisation of the University of Lancaster Library, is reproduced as Figure 2.1 on page 5. (Other types of internal organisation could equally well be represented by a similar method.) It assumes an inflow of recommendations for purchase; these items are then ordered, although some proportion of them will, for a variety of reasons, not be ordered or not be supplied. Books arriving are accessioned and passed to the cataloguing department. Simultaneously individual or bulk donations and bulk purchases may also arrive: these are accessioned rather differently, and some of them will be passed on for normal cataloguing while others will be consigned to a closed access store ("Alphabetical Store") after brief cataloguing ("shortlisting"). After cataloguing the books will be split into two streams: one will be labelled and shelved: the other will be despatched to the binders before being shelved. Meanwhile a flow of cataloguing data will result in the production of catalogue cards to be filed in the catalogues.

A computer program representing this model was written and is documented in some detail in Appendix A.1. Figure 2.2. on page 6 shows two extracts from one simulation experiment in which the technical processes model was simulated over a thirteen week period, using input data loosely derived from the University of Lancaster Library.

This particular piece of modelling was designed to examine the effect of various possible allocations of labour within the technical processing departments on the build-up or decline of backlogs and the delays involved. For this purpose it is necessary to assume various workrates, but the details of the actual processes are quite irrelevant; the technique can be applied to any similar library situation provided that a suitable flow-chart is available and that input data (work-rates, labour available, backlogs etc.) are sufficiently accurately established. This is, however, only one part of the total problem; it should be noted, for example, that the model could spell out the consequences of the adoption of a briefer form of cataloguing in terms of the effects this would have on cataloguing arrears and labour needs, but it could not attempt to assess the impact of such briefer cataloguing on the library's users,

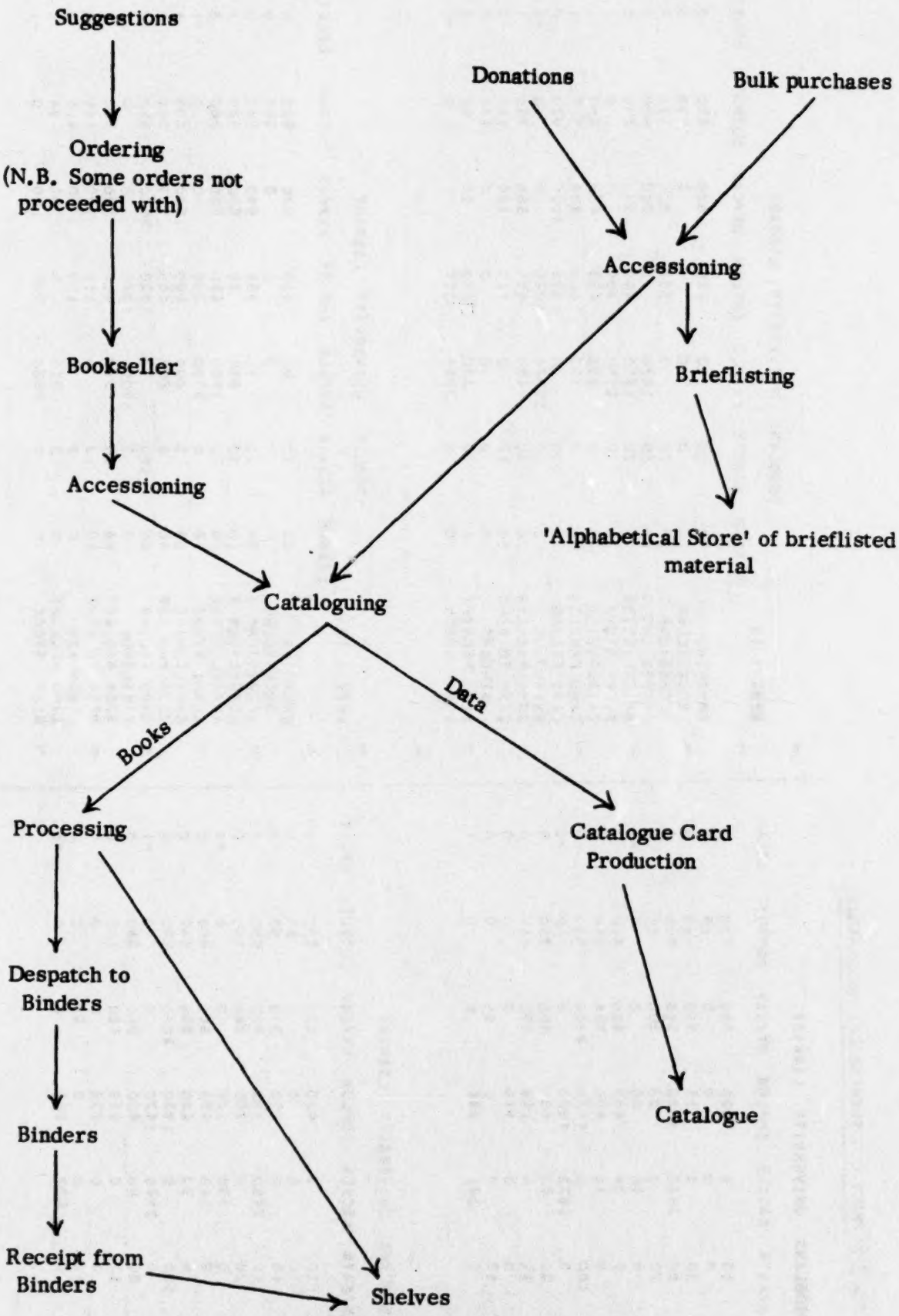


Figure 2.1. Summary logic diagram of book processing model

Fig. 2·2: PRINT-OUT FROM MODEL PROGRAMME

WOODLAND UNIVERSITY LIBRARY

WEEK 1 1

	LABOUR	W/RATE	BACKLG	INFLOW	WK/CAP	OUTPUT	DELAY
ORDERING	42	10	0	420	420	420	0
BOOKSELLER	0	0	0	0	0	15	0
ACCESSIONS 1	35	10	0	15	350	15	0
ACCESSIONS 2	10	50	2510	3010	500	500	5
BRIEFLISTING	10	20	0	50	200	50	0
ALPHA STORE	0	0	50	50	0	0	-1
CATALOGUING	80	5	65	465	400	400	0
CARD PROCESS	48	8	16	400	384	384	0
CARD FILING	20	100	0	1920	2000	1920	0
CATALOGUE	0	0	1920	1920	0	0	-1
BOOK PROCESS	18	20	40	400	360	360	0
DESP TO BIND	10	12	0	119	120	119	0
BINDERS	0	0	0	119	0	0	0
BIND RECEIPT	8	12	0	0	96	0	0
BOOK STOCK	0	0	241	241	0	0	-1

WOODLAND UNIVERSITY LIBRARY

WEEK 1 2

	LABOUR	W/RATE	BACKLG	INFLOW	WK/CAP	OUTPUT	DELAY
ORDERING	42	10	0	420	420	420	0
BOOKSELLER	0	0	0	0	0	53	0
ACCESSIONS 1	35	10	0	53	350	53	0
ACCESSIONS 2	10	50	2160	150	500	500	4
BRIEFLISTING	10	20	0	100	200	100	0
ALPHA STORE	0	0	150	100	0	0	-1
CATALOGUING	80	5	118	453	400	400	0
CARD PROCESS	48	8	32	400	384	384	0
CARD FILING	20	100	0	1920	2000	1920	0
CATALOGUE	0	0	3840	1920	0	0	-1
BOOK PROCESS	18	20	80	400	360	360	0
DESP TO BIND	10	12	0	119	120	119	0
BINDERS	0	0	0	238	0	0	0
BIND RECEIPT	8	12	0	0	96	0	0
BOOK STOCK	0	0	482	241	0	0	-1

WOODLAND UNIVERSITY LIBRARY

WEEK 1 12

	LABOUR	W/RATE	BACKLG	INFLOW	WK/CAP	OUTPUT	DELAY
ORDERING	42	10	60	420	420	420	0
BOOKSELLER	0	0	0	0	0	355	0
ACCESSIONS 1	35	10	5	355	350	350	0
ACCESSIONS 2	10	50	1430	0	500	500	3
BRIEFLISTING	10	20	1250	450	200	200	6
ALPHA STORE	0	0	2100	200	0	0	-1
CATALOGUING	80	5	298	400	400	400	1
CARD PROCESS	48	8	192	400	384	384	1
CARD FILING	20	100	0	1920	2000	1920	0
CATALOGUE	0	0	23040	1920	0	0	-1
BOOK PROCESS	18	20	480	400	360	360	1
DESP TO BIND	10	12	0	119	120	119	0
BINDERS	0	0	0	0	0	428	0
BIND RECEIPT	8	12	332	428	96	96	3
BOOK STOCK	0	0	3323	337	0	0	-1

WOODLAND UNIVERSITY LIBRARY

WEEK 1 13

	LABOUR	W/RATE	BACKLG	INFLOW	WK/CAP	OUTPUT	DELAY
ORDERING	42	10	60	420	420	420	0
BOOKSELLER	0	0	0	0	0	355	0
ACCESSIONS 1	35	10	11	355	350	350	0
ACCESSIONS 2	10	50	950	20	500	500	2
BRIEFLISTING	10	20	1500	450	200	200	8
ALPHA STORE	0	0	2300	200	0	0	-1
CATALOGUING	80	5	298	400	400	400	1
CARD PROCESS	48	8	208	400	384	384	1
CARD FILING	20	100	0	1920	2000	1920	0
CATALOGUE	0	0	24960	1920	0	0	-1
BOOK PROCESS	18	20	520	400	360	360	1
DESP TO BIND	10	12	0	119	120	119	0
BINDERS	0	0	0	119	0	428	0
BIND RECEIPT	8	12	236	0	96	96	2
BOOK STOCK	0	0	3660	337	0	0	-1

which is a rather different problem.

Note: For a description of another computer simulation of these processes see K. Mullick: Optimal design of a stochastic system with dominating fixed costs. Ph. D thesis. Johns Hopkins University. 1965. (University microfilms order no. 65-10, 449).

CHAPTER 3: THE STRUCTURE OF LIBRARY USAGE

3.A. Introduction

Since the aim of the project was to explore and to analyse the interactions which take place in the provision and use of library services, it was clear that any study of the regulation of the flow of material into a library ought to be matched by a serious consideration of the impact of flows of various sizes on the users of the library. How large ought the library to be? For how long should the documents, so painstakingly added to stock, be retained? Does a law of diminishing returns operate with respect to collection size and, if so, how?

Definitive answers to these difficult, but very important, questions must await a better understanding of the process of the dissemination of information and, more especially, a deeper knowledge of the behavioural patterns of library users; nevertheless, the structure of the problem can be clarified by a careful consideration of the factors involved. The traditional concentration of attention on the literature usage of scientists has resulted in a comparatively advanced understanding of its patterns (especially the use of serials), but there is relative ignorance about literature usage in the humanities - especially the use of monographs. Consequently the following discussion of document collections and the structure of their usage is based on patterns which are well-established in the case of scientific serials, but much less well-established in the case of monographs and non-scientific serials. There are, however, good reasons for believing that these latter follow essentially the same, or very similar patterns.

In considering the amount of material flowing into a library, one should look for evidence that the benefits of increased size are failing to keep pace with the costs of increased size. In brief, one should seek a law (or laws) of diminishing returns, and examination of the literature of librarianship reveals that at least two are well-established.

3.B. The implications for library management of two laws of diminishing returns

Dr. S.C. Bradford, then Librarian of the Science Museum Library in London, investigated the extent to which literature on a given topic was "scattered" over different journals(26). He ranked the individual journal titles according to the number of references on a given topic contained in them, and examined the progressive diminution of usefulness as more and more marginally relevant journals were considered. This followed a particular pattern now known as Bradford's Law of scattering: it is, in effect, a law of diminishing returns with respect to the number of titles in a collection. One formula for this law, given by Leimkuhler(150), states, with slightly different notation, that if R_N references on a given subject are derived from N journals then the n most productive journals would yield R_n references, where

$$R_n = R_N \frac{\log (1 + \beta n/N)}{\log (1+\beta)}$$

or $$R_n = \alpha R_N \log (1+ \beta n/N)$$

where $$\alpha = 1/\log(1+\beta)$$

and is a constant characteristic of the subject field and the logarithm is to base e. This implies that the nth most productive title yields r_n references where

$$r_1 = R_1$$

$$r_n = R_n - R_{n-1} \qquad n>1$$

Better known than Bradford's Law of scattering is the fact that the use made of a document tends to diminish as the document becomes older: this law of obsolescence is in effect a law of diminishing returns with respect to length of retention. One formula for this law, given by Cole(57), states that if $r_n(x)$ is the number of r_n references which are older than x years, then

$$r_n(x) = r_n e^{-\lambda x}$$

where is a constant characteristic of the subject concerned.

Now, since we have a well-established law of diminishing returns with respect to the number of titles acquired, and also a well-established law of diminishing returns with respect to the length of time one retains a document, it should be possible to combine these two laws and to analyse the implications of a variety of different managerial decisions with respect to user satisfaction, cost minimisation and so on. The remainder of this section gives examples of the use of this combination.

Example no. 1 Potentially most useful stock pattern

If we assume that a library can accommodate M volumes, then how many titles n, retained for x years, would give the most useful service? It is assumed that all titles are kept for the same length of time before being discarded (x years), and for present purposes we define a volume as one title/year. The definition of "most useful" (which we retain throughout these examples) is "that which provides maximal satisfaction level" - i.e. the stock which meets the largest amount of the demand falling upon the library. The problems caused by lending and the effects of duplication will be discussed in chapter 6.

Demand will be characterised by R_N references to N journals. If all N titles are acquired and retained for ever, then the total unsatisfied demand is zero; otherwise the unsatisfied demand U is made up of two components:

(i) the journals which are not taken: $R_N - R_n$

(ii) the parts of journals which were taken but which have been discarded at the age of x years: $R_n e^{-\lambda x}$

Therefore $U = (R_N - R_n) + R_n e^{-\lambda x}$

Now if we assume that the n titles are the n most productive of the total of N, then

$$R_n = \alpha R_N \log(1 + \beta n/N)$$

so that $U = (R_N - R_n) + R_n e^{-\lambda x}$

$$= R_N + R_n (e^{-\lambda x} - 1)$$

$$= R_N \left\{ 1 + \alpha (e^{-\lambda x} - 1) \log (1 + \beta n/N) \right\}$$

Now $M = nx$

so that $U = R_N \left\{ 1 + \alpha (e^{-\lambda M/n} - 1) \log (1 + \beta n/N) \right\}$

When we select the value of n (number of titles) which corresponds to the minimal value of U (unsatisfied demand), we have the most useful stock pattern. This is fundamentally the same approach as that of Cole(57), who produced data on scattering and obsolescence in the field of petroleum. He showed that, in a petroleum library which can accommodate about 2, 000 volumes, about 190 titles all retained for about 11 years would constitute the most useful stock pattern and would satisfy about 75% of the requests.

Example 2: Best value for money

In the previous example, the aim was to establish the best use of limited space: the M most useful volumes. A more practical question is how to make the best use of a limited amount of money.

We assume a budget of £B per annum which must pay for:

(i) Acquisitions

(ii) Storage (in the form of rent - or rent-equivalent as interest on capital investment - light, heat and other overheads).

How many titles, n, retained for x years would give the best value for money? What is the best allocation of the budget between acquisitions and storage?

Let c_1 be the average cost per title per annum and c_3 be the average storage cost per volume per annum. Since each of n titles is to be retained for x years.

$$B = n(c_1 + c_3 x)$$

$$\therefore \quad n = \frac{B}{c_1 + c_3 x}$$

Of the total demand of R_N references, we know that the number of references in the n most productive titles is R_n where

$$R_n = \alpha R_N \log (1 + \beta n/N)$$

Since $R_n e^{-\lambda x}$ references occur after the n titles have been discarded at age x, the usefulness of the collection will be

$$R_n - R_n e^{-\lambda x} = R_n (1 - e^{-\lambda x})$$

$$= \alpha R_N (1 - e^{-\lambda x}) \log (1 + \beta n/N)$$

Substituting for n we have

$$\alpha R_N (1 - e^{-\lambda x}) \log [1 + \beta B/(c_1 + c_3 x)N]$$

and we choose the value of x which corresponds to the maximum value of this function. Having established x (retention period) we can readily determine n (number of titles), and the use of these values will result in the optimal policies. The effect of variations in B (the budget)

can readily be calculated.

This analysis can conveniently be illustrated by calculating optimal policies for two imaginary petroleum libraries which have identical user-populations; one is in the city centre where storage costs are high, the other in a rural area where storage costs are low.

	City library	Rural library
Assumptions		
Annual acquisitions cost	£5 per title	£5 per title
Annual storage costs	£0.125 per vol.	£0.033 per vol.
Requests received	2, 000 per annum	2, 000 per annum
Conclusions		
If annual budget £1, 000		
Titles taken	140	175
Retention period	18 years	22 years
Vols. in stock	2, 520	3, 850
Requests satisfied	76%	80%
If annual budget £1, 500		
Titles taken	205	260
Retention period	18 years	23 years
Vols. in stock	3, 690	5, 980
Requests satisfied	83%	88%

This approach can be extended to include choice of binding policies, with specific reference to the question of deciding how much extra it would be worth paying to have binding done more quickly, thereby reducing the frustration caused to users by the absence from the shelves of material at binding.

Let a be the age that material is sent to binding
b be the time taken for binding
c_2 be the average binding cost per title per annum, which will depend upon the choice of binding time b.

Since n titles are to spend b time at binding and be discarded after x years

$$B = n(c_1 + c_2(b) + c_3 . x)$$

$$\therefore \quad n = \frac{B}{c_1 + c_2(b) + c_3 . x}$$

Of the total demand of R_N references, we know that the number of references in the n most productive is R_n where

$$R_n = a R_N \log (1 + \beta n/N)$$

The number of references satisfied before titles are sent to binding at age a is

$R_n - R_n e^{-\lambda a}$. The number satisfied after a period of b time at binding will be $R_n e^{-\lambda (a+b)}$, less those lost by discarding at age x, which amount to $R_n e^{-\lambda x}$. The total usefulness of the collection will, therefore, be

$$R_n - R_n e^{-\lambda a} + R_n e^{-\lambda (a+b)} - R_n e^{-\lambda x} = R_n (1 - e^{-\lambda a} + e^{-\lambda (a+b)} - e^{-\lambda x})$$

Substituting for R_n and then n, this becomes

$$\alpha R_N (1 - e^{-\lambda a} + e^{-\lambda (a+b)} - e^{-\lambda x}) \log [1 + \beta B/(c_1 + c_2 (b) + c_3 x)N]$$

The values of b (binding time) and x (retention period) which maximise this function denote the best combination of policies. The effect of variations in B (the budget) and a (time of binding) can be easily determined.

Example 3: Minimal costs and minimal delays

The two examples above assume that all titles are retained for the same period of time. This assumption has the virtue of simplicity, but unless the existence of scattering and decay be denied, it must necessarily lead to less than optimal results. Far more effective is the policy of retaining heavily-used titles for a longer period than less heavily-used ones. In fact, as the usage of each volume declines with time there comes a point at which it would be cheaper to satisfy by interlibrary loan such requests as still occur rather than continue to incur storage costs. (For the purposes of exposition, the unit cost of discarding material has been assumed to be trivial; in practice this might not be true, and the situation could arise where it is cheaper not to discard even if a document is totally unused. This would be the case should the unit cost of discarding, if devoted to some other purpose (e.g. invested in a bank), produce a greater benefit than the anticipated saving in storage costs.)

If requests for items not in stock are to be satisfied by interlibrary loan, then what combination of purchasing and discarding policies will minimise library costs? It is not assumed that all titles are retained for the same length of time; there are, therefore, two alternative methods of satisfying requests:

(i) by acquisition and storage of titles;

(ii) by interlibrary loan.

Let c_1 be the average acquisition price per title per annum,

c_3 be the average storage cost per volume per annum,

c_4 be the average cost per interlibrary loan,

F be the total overall cost,

m be the number of titles purchased,

and r_n be the total number of requests for the nth title.

The total cost F will be composed of four parts: the sum of the acquisition costs of the m titles acquired; the sum of the storage costs of the volumes purchased but not yet discarded at age x_n; the sum of the interlibrary loan cost of requests for material previously discarded and the sum of the interlibrary loan costs for titles not acquired at all.

$$F = \sum_{n=1}^{n=m} C_1 + \sum_{n=1}^{n=m} C_3 . x_n + \sum_{n=1}^{n=m} C_4 . r_n e^{-\lambda x_n} + \sum_{n=m+1}^{n=N} C_4 . r_n$$

The problem is to determine the values of $x_1, x_2, x_3 \ldots x_N$ and m which minimise F.

If we consider the retention policy only in terms of whole years, then $x_1, x_2, x_3 \ldots x_N$ can only have integer values and a convenient approximation can be achieved by examining each title separately. The total number of requests for the nth title is

$$r_1 = R_1$$

$$r_n = R_n - R_{n-1} \qquad n > 1$$

Furthermore, the volume of the nth title which is x_n years old is likely to be subject to

$$r_n e^{-\lambda (x_n - 1)} - r_n e^{-\lambda x_n} \text{ requests}$$

The cost of satisfying these requests by interlibrary loan would be

$$C_4 (r_n e^{-\lambda (x_n - 1)} - r_n e^{-\lambda x_n})$$

It is clearly economical to retain any purchased title until the age at which its usefulness has dropped to the level at which the requests which still occur can be more cheaply satisfied by interlibrary loan than by continued storage. In other words the best x_n is the highest value of x_n for which

$$C_4 (r_n e^{-\lambda (x_n - 1)} - r_n e^{-\lambda x_n}) > C_3$$

However, in view of the cost of purchasing the title in the first place, it might still not be worth acquiring. The number of requests which it would satisfy before being discarded is

$$r_n - r_n e^{-\lambda x_n}$$

and it would only be worth purchasing if the cost of satisfying these requests by interlibrary loan were more than the combined cost of purchase and storage whilst retained, i.e.

$$\text{if } C_4 (r_n - r_n e^{-\lambda x_n}) > C_1 + C_3 . x_n$$

The minimal cost occurs, then, when for each title the largest value for x_n (discarding age) is selected which satisfies the condition

$$C_4 (r_n e^{-\lambda (x_n - 1)} - r_n e^{-\lambda x_n}) > C_3$$

and a title is only to be acquired if it can satisfy the condition

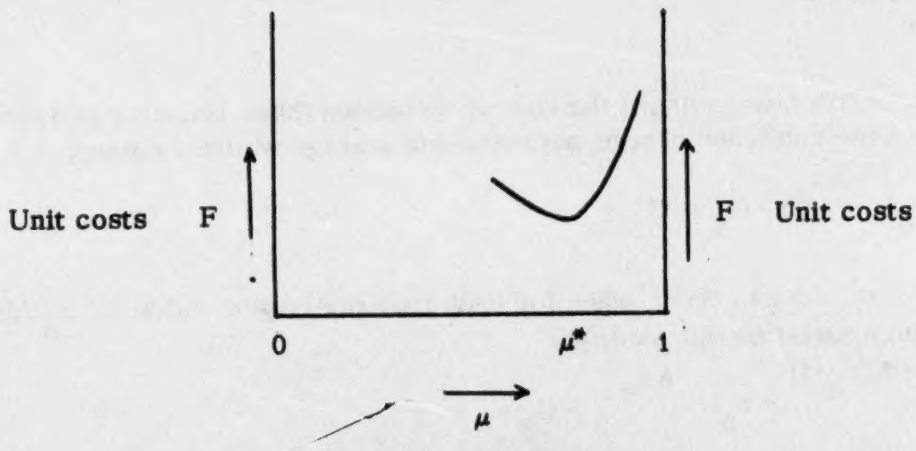
$$C_4 (r_n - r_n e^{-\lambda x_n}) > C_1 + C_3 . x_n$$

The number of titles which satisfies this last condition gives the optimal value of m.

In this way we can determine a minimal cost policy for our imaginary petroleum libraries

	City library	Rural library
Assumptions		
Acquisitions cost	£5 per title	£5 per title
Storage cost	£0.125 per vol.	£0.03 per vol.
Interlibrary loan cost	£1 per loan	£1 per loan
Conclusions		
Titles taken	50	60
Retention range	11-24 years	16-30 years
Total volumes	744	1, 230
Overall cost (F)	£1, 160	£1, 095
Satisfaction from stock	58%	63%

As the figures above imply, there is in any given circumstances a solution which minimises the cost to the library budget of meeting a given demand, and this solution involves satisfying a particular proportion of demand from stock. However, it might very well be decided, as a matter of managerial policy, deliberately to choose a solution other than that of minimal cost to the library. This alternative solution can be calculated by defining V as the marginal rate of usefulness and substituting it for c_4 in the restrictions above. A value of V is then selected which will result in the desired percentage of satisfaction from stock being achieved at least cost. For example, material not stored locally seems discouragingly inaccessible, and the satisfaction of requests by interlibrary loan necessarily involves some delay to the reader: the mean delay will be more or less directly determined by the proportion of requests satisfied by interlibrary loan - the smaller the proportion, the smaller the mean delay. However, as has just been shown, there is, in any given circumstances, a solution of minimal cost to the library. As the size of the collection is increased (so that the proportion of requests satisfied from stock increases from zero to the point of minimal library costs - μ^* in the graph below) so both mean delay and costs are reduced.



However, if the size of the collection is increased, the proportion of requests satisfied from stock, μ , is increased beyond μ^*. This means that the continuing reduction in mean delay is only achieved at the price of ever more rapidly increasing unit costs. If data on the cost associated with various delays and/or degrees of accessibility were available then a truly

optimal solution could be established; until then, we can establish the effects on delays and on unit costs of any given choice of μ and use the information derived to help in making a subjective choice. Against this, it must be remembered that even if interlibrary loans are being arranged as speedily as possible at any given unit cost, the delays can generally be reduced by other kinds of investment than increasing collection size - for example by using telex, telephone or telefacsimile. In particular, increased investment in improving national lending facilities might well be a more economical solution, in national terms, than the summed costs of increased collection size at each local service point.

Summary

The three-dimensional structure of the pattern of library usage implied by these two laws of diminishing returns is represented graphically in Figure 3.1 on page 16.

OP represents the collection size in number of titles, and OQ the length of time that titles are retained. The vertical dimension represents the intensity of use of material in any given position, defined by its age (OQ axis) and by its ranking in the pattern of scattering (OP axis). The thin lines represent the contours of equal intensity of usage on the concave upper surface. Diagram A shows the type of stock pattern given in examples 1 and 2 above, where n′ titles are all retained for x′ years. Since the collection size is defined by the area On′ Ex′ , the demand it can meet is represented by the volume of space ABCDOn′Ex′ .

Similarly Diagram B shows the solution in example 3 above, in which titles are not all kept for the same period of time, but only until usage has dropped to a common threshold, which is represented in this case by the contour DF. However, titles in the region $n - P > n''$ have so little use that they are not worth acquiring in the first place; consequently the collection is denoted by the area On′′Ex′′ , and the volume of demand satisfied by this collection profile is denoted by the volume of the space ABCDOn′′Ex′′ .

The number of variables in the examples is simply a reflection of the number of factors involved in library management.

Conclusion

In the examples above it was implicitly assumed that the proportion of provision from stock would not affect the pattern of demand. Since physical accessibility is known to be a factor affecting the demand for library services, as Harris(108), Rosenberg(211, 212) and Allen and Gerstberger(2) have demonstrated, it is likely that, with present technology, items not in stock will seem less accessible to the user even though he may have access to excellent interlibrary loan facilities; consequently users may tend not to request an item on interlibrary loan even though they would have consulted it had it been on the shelf. This aspect of user behaviour clearly needs further examination. Even so, the obsolescence of literature and Bradford's Law of scattering are potentially powerful tools in the analysis of library systems.

The work outlined in the examples above was carried out in the summer of 1967 and is described more fully in Buckland, M. K. and Woodburn, I. Some implications for library management of scattering and obsolescence. (University of Lancaster Library Occasional Papers, No. 1). 1968. The interested reader is also recommended to read a paper by Mr. B. C. Brookes entitled 'Statistical distributions in libraries and documentation' which has been published in Planning library services; edited by A. G. Mackenzie and I. M. Stuart. (University of Lancaster Library Occasional Papers, No. 3). 1969.

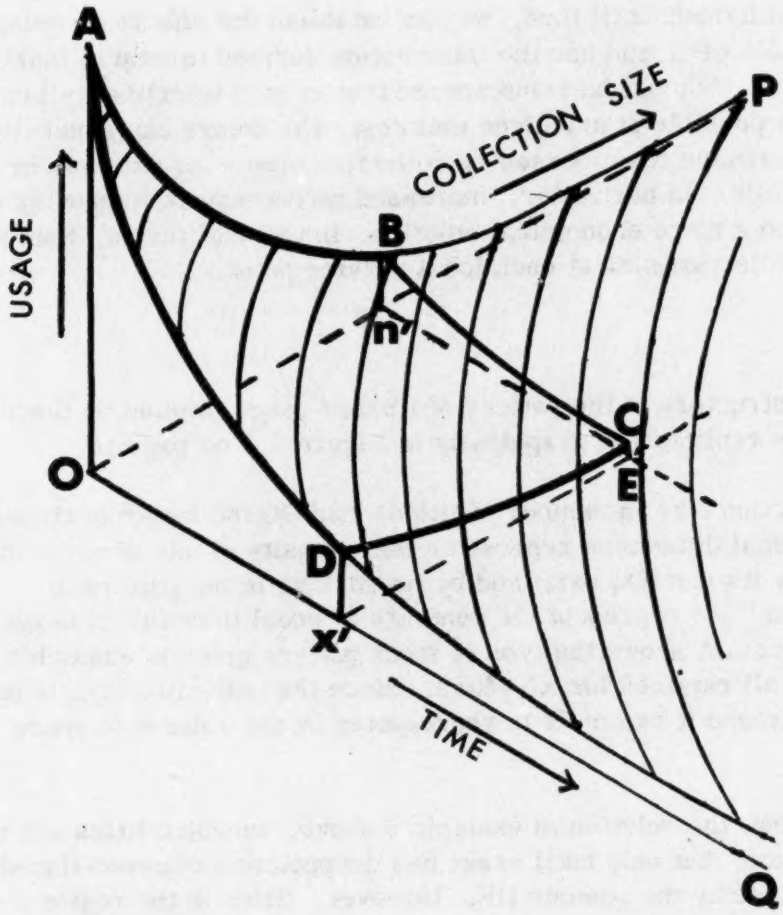


DIAGRAM 'A'

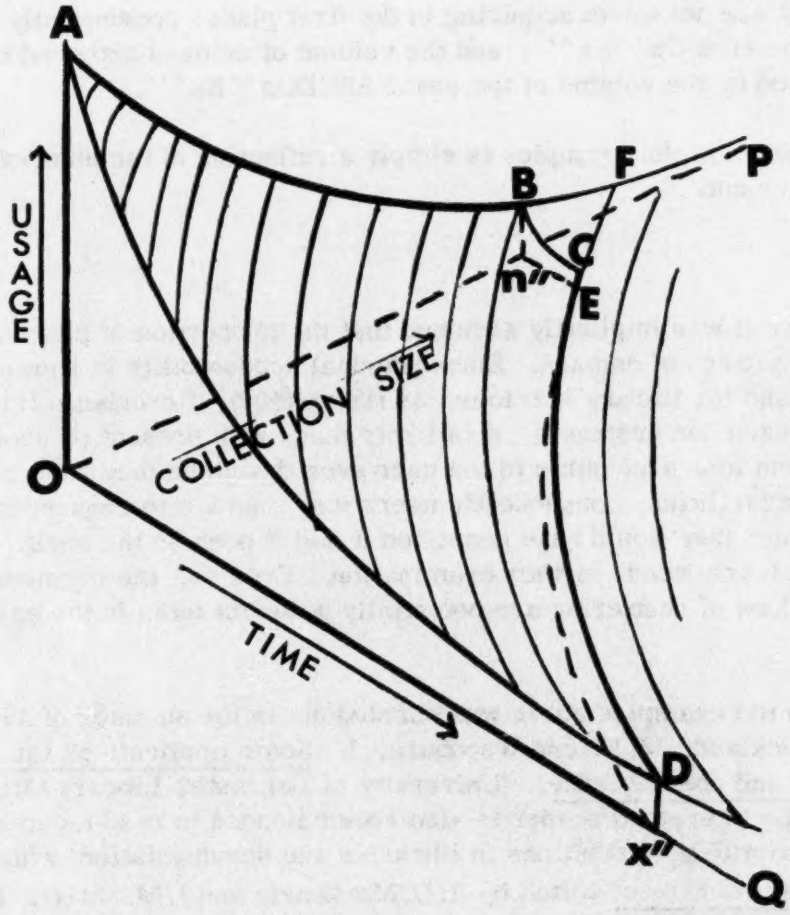


DIAGRAM 'B'

Fig 3·1: THE STRUCTURE OF LIBRARY USAGE

3.C. Scatter, decay and inertia: Zipf and others

As work on this project progressed it became increasingly clear that statistical patterns similar to Bradford's Law of scattering recurred widely in librarianship and information science. It also seemed that the further investigation of the nature and the implications of these patterns, as in the previous section, could be of enormous importance. These thoughts were strengthened by the publication of an article by Kozachkov and Khursin entitled 'The basic probability distribution in information flow systems'(141) which describes the fundamental similarity of a number of known similarities in the flow of information. They propose a basic model, called the 'hyperbolic ladder', and relate it, in particular, to work in linguistics by Zipf, in documentation by Bradford, and in the science of science by Lotka.

Zipf's work was based upon his studies of the relative frequency with which different words occur, and especially a characteristic frequency distribution - a rectangular hyperbola (where $x.y = C$) for a rank/frequency graph. Zipf's law states that the number of occurrences of a work in a long stretch of text is the reciprocal of the order of frequency of occurrence: a feature which had earlier been observed by S.B. Estoup(263). This distribution was found to fit a wide range of languages and texts, and Zipf extended his work to cover a wide variety of non-linguistic activities.

Zipf first published his treatise on 'dynamic philology'(264) in 1933 and Bradford propounded his 'Law of scattering'(26) in 1934. Zipf published his magnum opus(263) in 1949; Bradford in 1948 (25).

A number of writers have commented on the similarity of the work of Zipf and Bradford, notably Fairthorne(81, 82), Kendall(134), Kozachkov and Khursin(141) and Brookes(29).

In so far as both journal articles and words are items of information used in a wider process of communication, the analogy between scientific literature and natural language is not entirely fanciful - least of all when journal use frequency follows the same pattern as word-use frequency as revealed in mathematical linguistics. Work on Bradford's Law of scattering has been based largely on citation analysis, but the same results are reported when actual usage is examined (e.g. Bourne(22), Fleming and Kilgour(84)). A variation of Bradford's theme is reported by Kendall(135) who analysed the distribution by author of references in one of his own books, and found that the same pattern emerged.

Zipf himself examined the distribution of lengths not only of concert items, newspaper reports, and encyclopaedia articles but also the lenth of monographs in the catalogue of Harvard College library, as measured by the number of pages. In each case the same general 'Zipf curve' is found(263). Subsequently Saxena has reported that book height, which is perhaps less closely related to the information flow than is the length of the text, follows a different pattern(216).

Another aspect of monograph usage which has been curiously neglected is the distribution of usage over different titles. Bradford's Law of scattering has been referred to as a 'law of libraries', but in fact its relevance to documents other than journals has hardly been examined. There is, however, fragmentary evidence in work by Fussler and Simon(86), Trueswell(237), and Lörincz(158) that a similar pattern emerges.

It is not, however, only in the usage of library services that a Zipf-type curve has been observed, but also in a human aspect of the provision: subject indexing. Raver(204) has reported: 'Descriptors are not used with the same frequency, some occurring very often and others very seldom. If we plot the frequency of usage of the different descriptors,

we obtain the so-called Zipf curve'. More recently an experiment by the Co-ordinate Indexing Group has been shown by Dammers(68) to reveal a Zipf-type curve in the distribution of descriptor usage and a similar kind of mathematical relationship between the number of documents indexed and the number of different descriptors employed. Perhaps the fact that descriptors in a subject index follow the same statistical pattern as that revealed by mathematical linguistics in natural language should have been expected: subject indexing systems, being composed of items manipulated to transmit information, have sometimes been regarded as languages - or 'meta-languages' - a theme treated at length in Coyaud's Introduction à l'étude des languages documentaires(65). It would, therefore, be all the more appropriate to find a similar pattern in them both.

Apart from the use and provision of information services, the same distribution is evident in the original sources of information. The distribution of authors according to the number of articles they write was shown by Lotka(159) in 1926 to follow a pattern similar to that later propounded by Zipf.

One non-linguistic field in which Zipf's work has led to a considerable amount of work is regional planning - notably in the derivation of 'gravity models' for such problems as planning shopping centres(187). The effect of distance on academic library use has been somewhat neglected, but an exponential fall-off with distance of use of public libraries is well established. The law of retail gravitation has in fact been used to help select public library sites(209).

In this context it may be observed that there are a number of other aspects of library use which follow a negative exponential form, often similar to the rectangular hyperbola. For example, the best known statistical regularity in librarianship is the fact that when the use of documents is plotted against their age a negative exponential pattern is revealed. This has been extensively studied in the case of journals (Bourne(22)) and also of monographs (Jain(129)). A study at M.I.T. of the length of stay on each visit to the Science Library revealed a negative exponential pattern - albeit with two populations(35).

Zipf's studies of word frequency were supplemented by an elaborate explanation of the pattern revealed, and he argued that every individual's entire behaviour is governed by the Principle of least effort or 'the least average rate of probable work'. The explanation has received heavy criticism; and yet the pattern revealed by Zipf is an economical one: the more frequent use of long words instead of short ones would require more effort. However, most linguists regard language as primarily the spoken word and it seems a little surprising that speech should be dictated by factors such as the number of letters in a word. In the social and economic manifestations of Zipf's law, especially those concerned with distance (such as retail shopping gravity models), the conflict between the relative attractiveness of larger centres and the desire to minimize travelling effort provides a very plausible explanation.

In the field of libraries, where apparent manifestations of Zipf's law are evident, there is independent evidence that convenience is a dominant factor in determining library use. Rosenberg(211, 212) surveyed by psychometric techniques the attitudes of ninety-four scientists in industrial and governmental environments, only some of them engaged in research, and inferred that 'the ease of use of an information gathering method is more important than the amount of information expected'(211).

Allen and Gerstberger(2), investigating scientists' criteria for selection of an information source, reported 'a direct relationship between accessibility of information channels and several objective measures of utilization, whereas no definite support is found for the

hypothesis that the channels perceived highest in technical quality are those used most frequently'. Harris(108) has examined the influence of physical accessibility on a variety of aspects of university library use by students. In each case increased physical accessibility resulted in greater use and 'there are many situations in which the absence of reasonable accessibility will result in a complete absence of use'.

Some attempts have been made, using the apparatus of information theory developed by Shannon and Weaver, to clarify Zipf's ideas. For example, experimental studies have been carried out(128) in which reading times have been taken as indices of the effort involved in handling a word. The experimental results show a reasonable match with the hypothesis that human beings choose words in such a way as to transmit the maximum amount of information (in the 'information theory' sense) in a given time period. Word usage may be governed by economy of effort and this can perhaps be measured as economy of time. Mandelbrot(163) considers the problem of designing a least-cost vocabulary, and states that the problem is that of designing a vocabulary such that it transmits the maximum amount of information compatible with cost constraints. He shows that the distribution of word frequency in the ideal vocabulary follows a more general version of Zipf's law - a law fitting the data more successfully than does Zipf's formula.

This survey can be summarized in two sentences. Firstly, a wide variety of aspects of the transmission of information is characterized by a particular probability distribution. Secondly, convenience, or something in the nature of a Principle of Least Effort, is a dominant factor in at least some aspects of the transmission of information.

What significance, we must than ask, is there in this for library systems analysis? The answer would seem to be that these speculations deserve closer examination at three levels.

(i) Descriptive

How valid is the assertion that one kind of statistical distribution recurs in a variety of different situations? This can only be answered by the collection and examination of data in each particular case. This essentially descriptive work would seem in general to be worth doing even if its practical significance might seem at first to be limited. Bradford(24) observed in 1946 that his law 'conforms to the mathematician's criterion of being no possible practical use whatever',(24, p744) In fact, this was not true even then, because Bradford himself used it to draw some important conclusions concerning the extent to which abstracting journals could be expected to cover the relevant literature. Even if no more were achieved than a better theoretical understanding of a particular aspect of information transmission or library use, closer examination would seem worthwhile. For the most part, however, better understanding could be expected to lead to practical improvements.

(ii) Theoretical

The mere existence of a single pervasive distribution in a wide variety of aspects of the transmission of information is striking. The fact that there appears to be a unifying feature - human economy of effort - is also striking. Could these facts be used as the starting point for the development of some general theory of information transmission which is notably lacking in librarianship and information science? Could this be the means of achieving some degree of synthesis in the fragmented field of communications, between information theory and librarianship, linguistics and information flow studies?

(iii) Managerial

In the provision of library and information services there are many practical problems. Unfortunately the managerial problems have not been given as much attention as they deserve, and the literature of library management is somewhat barren. Efficient library management calls for more than technical skills in the provision of library services. These skills do not tell you how many documents to buy, how long to keep them, where the library should be, or how long the loan period should be. For this some understanding is needed of the likely consequences of such decisions concerning the type, scale, and manner of library provision in the complex ecological system of the library, its users, and the world at large. Progress in this area has depended largely upon the recognition, verification, and implications of the topics surveyed above: scattering and obsolescence, the randomness of request patterns, and the importance of ease of access.

Note: A version of the above section was published under the title 'Library Zipf' in the Journal of Documentation 25(1) March 1969, 52-57. The next issue, in June 1969, contained correspondence. Subsequently Mr. R.A.Fairthorne has published a substantial review article entitled 'Empirical hyperbolic distributions (Bradford-Zipf-Mandelbrot) for bibliometric description and prediction' in the Journal of Documentation 25(4) December 1969, 319-343.

CHAPTER 4: THE INDIVIDUAL LIBRARY IN RELATION TO ITS USERS AND TO OTHER LIBRARIES

A. Introduction

Although this report is primarily concerned with the individual library, it must be remembered that libraries do not operate in isolation. No library can be entirely self-sufficing, and dependance on other libraries, especially for interlibrary loans, has become a normal and natural part of librarianship. In the previous chapter, it was shown that the ability to procure material and the speed with which this could be done was an important factor in the planning of libraries. In fact the problem of establishing a balance between storage of material at the local level and reliance on access to material elsewhere is of fundamental importance: local storage will be more accessible, but remote - perhaps centralised - storage may be more economical, in that less duplication will be needed. Indeed duplication and, therefore, storage costs would be minimised by having one single central library from which all documents could be borrowed as required. Against this must be set the transport costs and the 'cost' to the reader of using such relatively inaccessible material: although the user may not personally have to pay money for interlibrary loans, there is, nevertheless, an effort and a delay involved; this expenditure of effort and time can reasonably be called a 'cost' and must be taken into account if an overall view of the library service is to be taken. Each user has a limited amount of both time and energy at his disposal for his various activities, and the more of each which is involved in library use, the less is available for other activities such as teaching or research. Furthermore, and this is very important, his behaviour in general, and his library use in particular, is likely to be strongly influenced by his own expectations of the amount of energy and time required for various possible activities: it is well established, for example, that distance to a library is an important factor in determining the amount of use made of it.

So far discussion has concentrated on a two-level system: a local library plus inter-library loan facilities. In practice, it is common to have a system with more than two levels: for example, for most of the population of Great Britain, the nearest public library will be a branch library or a mobile library; backing that will be the central library of the local library service, and backing that will be the rest of the national library system. The library user in a university uses books which are commonly stored at four distinct levels of accessibility:

(1) a personal collection;
(2) a departmental library;
(3) a university library;
(4) other university libraries and national libraries.

Because material is more accessible at the lower levels (i.e. personal collections and departmental libraries) it is reasonable to suppose that, from the point of view of the individual, the best system at a given cost is one in which the most-used material belongs to his personal collection and so on by degrees until the least-used material is held at national level. Furthermore, the more there is at the lower, more accessible levels, the better it is for the user.

Although a personal library is established for the benefit of one individual, a departmental library must cater for demands from all its members. In practice it must cater for the sum of the residual demands from its members, since some of their demands will have been met from their own collections. Similarly, a university library must cater for the sum of the residual demands from all members of all its departments, and a national

library for the sum of the residual demands from all universities.

This principle, the principle of residual demand, has been used to establish a simple mathematical model for a hierarchical library system. The model will be described in mathematical terms and its use will be illustrated by means of a simplified but realistic example.

B. The Basic Model

Consider a library system which has four levels of storage:-

(1) Personal libraries
(2) Departmental libraries
(3) University libraries
(4) a National library

Let M be the total number of titles to be stored in the system, and let N be the total number of users of the system.

Let r^i_{jkl} be the expected number of demands in a specified period of time (e.g. one year) for the ith title from the jth user belonging to the kth department of the lth university.

Considering each storage level in turn:-

(1) Personal library: we assume that personal libraries hold all titles i for which

$$r^i_{jkl} \geq r^*$$

where r is the marginal level of demand below which the title is not held (for simplicity it is taken to be the same for all titles).

(2) Departmental library: let $r^i_{.kl}$ be the expected number of demands for the ith title from all members of the lth university.

Then applying the principle of residual demand we have

$$r^i_{.kl} = \sum_j r^i_{jkl}$$

where $r^i_{jkl} = 0$ if $r^i_{jkl} \geq r^*$ at the personal library level.

We assume that departmental libraries hold all titles i for which

$$r^i_{.kl} \geq r^{**}$$

where r^{**} is the marginal level of demand below which the title is not held and it is taken to be the same for all titles.

(3) University library: Let $r^i_{..l}$ be the expected number of demands for the ith title from all members of all departments of the lth university.

Then applying the principle of residual demand we have

$$r^{i}_{..l} = \sum_{k} r^{i}_{.kl}$$

where $r^{i}_{.kl} = 0$ if $r^{i}_{.kl} \geq r^{**}$ at the departmental library level.

We assume that University libraries hold all titles i for which

$$r^{i}_{..l} \geq r^{***}$$

where r^{***} is the marginal level of demand below which the title is not held and it is the same for all titles.

(4) National library: At this stage we have a choice: we can insist that the national library holds all titles, or we can define r^{****} to be the marginal level of demand below which the title is not held, and apply the principle of residual demand to discover which titles should not be stored at the national level. The first assumption seems more appropriate, and as the costs of duplication are small we assume that the national library holds all M titles.

At this stage it should be evident that the marginal levels of demand r^{*}, r^{**} and r^{***} constitute a storage policy for the system: if we change their values then we change the pattern of storage and also the way in which demands are satisfied. For any particular policy we can calculate the number of titles stored at each level and also the total number of demands satisfied from each level, and the total cost of providing the service can be calculated. Also if we define t^{*}, t^{**}, t^{***} and t^{****} to be the average times of access to material stored at personal, departmental, university and national levels respectively, then we can calculate the overall average time of access to the system.

One simplification that has been made at the outset is that material can only be transferred between libraries at distinct levels in the system: e.g. inter-University-library loans are treated as loans from a national library as far as cost and access times are concerned.

If we wish to compare two storage policies then we select two sets of values for the marginal levels of demand and simulate the operation of each system for a fixed pattern of expected demands r^{i}_{jkl}. The total cost and overall average access times for each system can then be compared.

The applicability of the model will be illustrated by means of a simplified but realistic example which highlights the information that is required before systems of this kind can be viewed objectively.

Application of the model

There are about 50 Universities with an average of 30 departments per University and a grand total of 250, 000 staff and students. It is most unlikely that the expected demand for each title from each of the 250, 000 users can be measured, and an alternative approach is therefore necessary. Personal libraries are excluded from the illustrative example, so that the basic quantities required are the $r^{i}_{.kl}$, i.e. the summed residual demands for the ith title from all members of the kth department of the lth university.

Even so there are about 7 million titles held by the British Museum library at the present time, and it is most unlikely that the expected demands for each of these titles could ever be measured. Therefore in the example the number of titles that have been considered is

restricted to what might be called "the most used scientific journals in the early 1950's".

The data that has been used to represent the quantities $r^i_{.kl}$ has been taken from C.H. Brown Scientific Serials (ACRL monograph 16) Chicago, ACRL, 1956. In the course of Brown's study he produced a consolidated alphabetical list of the 612 most frequently-cited scientific serials, classified according to the source journals in eight subject fields. The subject fields, together with the total number of journals cited and the total number of citations are listed in Table 4.1.

Table 4.1

	Journals cited	Citations
(1) Mathematics	179	3348
(2) Physics	320	9596
(3) Chemistry	275	10518
(4) Geology	490	2913
(5) Physiology	299	5984
(6) Botany	376	4995
(7) Zoology	663	2775
(8) Entomology	350	2326
TOTAL	2952	42455

The figure of 2925 journals cited includes some duplication but the data necessary to identify these are not recorded. However, if the number of journals cited five or more times on each of the eight subject lists are added together the total comes to 828 titles. Some of these titles occur on more than one subject list and there are 612 distinct titles in the consolidated list. It has been assumed in this example that there is no overlap in the less-cited journals, i.e. that they are classified into one subject heading only. This implies that 2925 - 828 + 612 = 2736 distinct journals were cited a total of 42455 times.

The degree of overlap of the 2736 cited journals can be measured by the number cited in 1, 2, 3 etc. subject fields. The complete distribution is contained in Table 4.2.

Table 4.2

No. subject fields	No. Journals cited
1	2617
2	67
3	34
4	6
5	4
6	4
7	2
8	2
	2736

The apparent lack of overlap in the basic data helps to explain the large part played by departmental libraries in the ensuing analysis.

The basic data for the simulation exercise is the array of numbers listed by Brown on

pages 143-154 of his book, and the first ten rows of the array are reproduced in Table 4.3 for the purpose of illustration.

Table 4.3

	Maths	Physics	Chem.	Geol.	Physiol.	Botany	Zool.	Entom.	TOTAL
Acad. Med. Belg. Bull.	.	.	.	.	10	.	.	.	10
Acad. Belg. Cl. Sci. Bull.	12	.	.	.	.	.	.	.	12
Acad. Sci. Paris, C.R.	125	213	239	16	19	173	43	16	844
Acad. Nat. Sci. Philad., Proc.	.	.	.	.	.	.	8	.	8
Acad. Lincei, Mem.	.	.	8	.	.	.	.	.	8
Acad. Lincei, R.	10	.	.	.	.	.	.	.	10
Acoust. Soc. Amer., J.	.	16	.	.	.	.	.	.	16
Acta chem. scand.	.	.	212	.	.	.	.	.	212
Acta cryst., Camb.	.	32	14	9	.	.	.	.	55
Acta Hort. berg.	.	.	.	.	.	11	.	.	11

In this exercise the array represents the quantities $r^{i}_{.kl}$ with the index i running over the 612 journals (or more accurately, the 2736 journals). The subject fields represent the departments i.e. k = 1, 2, 3, ..., 8.

For the sake of extreme simplicity it has been assumed that the library system must cater for 50 identical universities, each with 8 departments, and with identical demands for each of 2736 titles i.e.

$$r^{i}_{.kl} = \text{constant for all 1 universities}$$

Since the degree of overlap in expected demands is very important to the design of an efficient storage system, this simplification is not critical.

The time period is considered to be one year so that 42455 demands are made in one year for 2736 titles at each of 50 universities.

Another simplification has been made in defining alternative storage policies for the system, namely that the marginal levels of demand are equal at each level of storage i.e. $r^{**} = r^{***}$. In order to provide a wide range of results the levels that have been investigated are 5000, 2000, 1000, 500, 200, 100, 50, 20, 10 and 5 demands per annum.

Table 4.4 contains the number of titles stored and the number of requests satisfied from each storage level for each of these marginal levels of demand. The results apply to each of the 50 universities.

Operating costs

We assume that each demand generates one issue and return and that the unit cost of the pair of transactions is 1/-, from whatever storage level that demand is satisfied.

In addition a transfer charge is included for all demands satisfied from the national level; this covers postage and packing and a handling charge. It is not a fixed unit cost since

Table 4.4

Marginal level of demand	Departmental Titles	Departmental Requests	University Titles	University Requests	National Titles	National Requests
5000	NIL	NIL	NIL	NIL	2736	42455
2000	2	5606	NIL	NIL	2736	36849
1000	3	6762	NIL	NIL	2736	35693
500	7	9876	4	3105	2736	29474
200	38	18551	10	2940	2736	20964
100	68	22667	16	2329	2736	17459
50	135	27409	30	2169	2736	12877
20	308	32544	43	1186	2736	8725
10	568	36022	9	127	2736	6306
5	612	37834	NIL	NIL	2736	4621

economies of scale are important: a curve has been drawn for which the unit cost is 15/- when there are 150, 000 loans per annum, 10/- when there are 460, 000 loans per annum and 5/- when there are more than 2, 000, 000 loans per annum.

At this stage another simplification has been achieved by assuming that a single copy of each journal is sufficient to provide an adequate standard of service so far as the "immediate" availability of material is concerned. The impact of duplication and permitting borrowing will be discussed in Chapter 6. A cost of £15 per title is assumed.

These unit costs have been used to derive the following table of operating costs for the system as a whole.

Table 4.5

Marginal level of demand	Costs (£ per annum) Purchase	Issue	Transfer	TOTAL
5000	41, 040	106, 138	530, 688	677, 866
2000	42, 540	106, 138	460, 612	609, 290
1000	43, 290	106, 138	446, 162	595, 590
500	49, 290	106, 138	386, 846	542, 274
200	77, 040	106, 138	327, 562	510, 740
100	104, 040	106, 138	290, 983	501, 161 ←
50	164, 790	106, 138	265, 588	536, 516
20	304, 290	106, 138	223, 578	634, 006
10	473, 790	106, 138	189, 180	769, 108
5	500, 040	106, 138	155, 959	762, 137

The minimum operating cost is associated with the marginal level of demand of 100 which, on referring back to Table 4.4, is equivalent to a 40% level of loans from the national library (i.e. 40% of total loans are satisfied from the national library level). In fact on our assumptions costs do not vary greatly over the range 30-50% national library loans.

Access times

So far the only costs that have been considered are the costs of providing the service. We now go on to consider the costs that are incurred by the user, and we begin by defining

average times of access. These times are associated with the time it takes to obtain a book or a journal after the need for it has been recognised.

Times assumed are:

0.1 hours from a departmental library
0.5 hours from a university library
12 hours from a national library
(this last estimate represents 1.5 working days).

The overall average access times for the total number of demands are calculated from the results listed in Table 4.6 to be:

Table 4.6

Marginal level of demand	Overall average access times (hours)	Total annual operating costs (£)
5000	12	677, 866
2000	10.4	609, 290
1000	10.0	595, 590
500	8.4	542, 274
200	6.0	510, 740
100	5.0	501, 161
50	3.7	536, 516
20	2.5	634, 006
10	1.9	769, 108
5	1.4	762, 137

User costs

At this stage we have attempted to cost users's time in money terms so that an overall assessment of different storage policies can be made. However, because of the difficulties in estimating such costs it has been necessary to propose a number of alternative costings and examine the consequences of these. The costs that were selected are:-

40/- per hour
4/- per hour

In the case of the national library, the access time for costing purposes was reduced to 1 hour (i.e. two visits to the University Library) since it is reasonable to assume that the remainder of the 12 hours' wait would be used profitably for other purposes.

The total access times for all demands from each university (based on this revised figure, the annual user cost, the annual operating cost and the grand total cost) are listed in Tables 4.7 and 4.8 for unit user costs of 40/- per hour and 4/- per hour respectively.

The effect of including user costs is to reduce the part played by the national library. If the user cost is 4/- per hour then about 30% of loans should be satisfied from the national level, but if it is 40/- per hour then less than 10% of loans should be satisfied from this level.

Table 4.7

User cost 40/- per hour

Marginal level of demand	Total access time (hours) each univ.	Costs (£ per annum) user	operating	grand total
5000	42, 455	4, 245, 500	677, 866	4, 923, 366
2000	37, 409.6	3, 740, 960	609, 290	4, 350, 250
1000	36, 369.2	3, 636, 920	595, 590	4, 232, 510
500	32, 014.1	3, 201, 410	542, 274	3, 743, 684
200	24, 289.1	2, 428, 910	510, 740	2, 939, 650
100	20, 890.2	2, 089, 020	501, 161	2, 590, 181
50	16, 702.4	1, 670, 240	536, 516	2, 206, 756
20	12, 572.4	1, 257, 240	634, 006	1, 891, 246
10	9, 971.7	997, 170	769, 108	1, 766, 278
5	8, 404.4	840, 440	762, 137	1, 602, 577←

Table 4.8

User cost 4/- per hour

Marginal level of demand	Costs (£ per annum) User	Operating	Grand total
5000	424, 550	677, 866	1, 102, 416
2000	374, 096	609, 290	983, 386
1000	363, 692	595, 590	959, 282
500	320, 141	542, 274	862, 415
200	242, 891	510, 740	753, 631
100	208, 902	501, 161	710, 063
50	167, 024	536, 516	703, 540←
20	125, 724	634, 006	759, 730
10	99, 717	769, 108	868, 825
5	84, 044	762, 137	846, 181

C. Conclusions

The purpose of the modelling presented in the previous section was to clarify some of the factors involved and to serve as a basis for further discussion. Although a three-tier library structure was assumed, the methodology could be used to treat a system involving two, three, four or more levels in the same way.

One of the most important features of mathematical modelling is that a variety of data - real or imaginary - can be used to see what effect different data would have. The numerical results in the previous section are fictitious, and should be regarded only as illustrative of the methodology discussed. The data which have been used are of the type which is needed for a serious treatment of storage problems, but which is not available for use at present. Nevertheless the introduction of computers into libraries could revolutionise the availability of data, and it is clear that the development of techniques for measuring the expected demand for books and journals is a matter of pressing importance. Similarly the degree of overlap in literature usage by different disciplines is also a critical factor in studies of this type.

CHAPTER 5: THE PATHOLOGY OF LIBRARY PROVISION

PART 1: HINDRANCES AT THE LOCAL LEVEL

So far in this report we have been considering the size of a library and its relationship with its users and with other libraries; we have assumed that if a document is in a library, then it is available for those who need it. In this chapter and in the following chapter we examine more closely the availability of books belonging to a library, and record our attempts to isolate and quantify the factors which do in practice interfere with the availability of books. This chapter deals with the identification of the relevant factors, the quantitative assessment of their relative importance, and an account of some steps taken to improve the library service at Lancaster. In the following chapter work on lending and duplication is described in some detail.

A. Factors affecting the availability of books

On Thursday 14 March 1968 a survey was conducted at the main university library at Bailrigg. This survey had two aims:

(i) To attempt a 'frustration survey': that is, to try to get some idea of the various factors which prevent a desired document being found by the person seeking, and to obtain a quantitative measure, however approximate, of the relative importance of these factors.

(ii) To attempt to measure the amount of reference (or 'unrecorded') use made of the library - and, if possible, to relate it to the amount of borrowing (or 'recorded') use.

A questionnaire was designed to extract numerical answers (a copy is reproduced as Figure 5.1). Since a measure of actual use of the library was intended, a copy was handed to each person entering the library on that day, which had been selected partly for the convenience of the surveyors and partly because it appeared to be typical. Readers entering the library more than once during the day were asked to record their activities during their second or subsequent visit on a new questionnaire, or alternatively to add further information to their first questionnaire. A count was made of the number of questionnaires handed out and also of the number of visits. At the exit a box was prominently displayed with a notice asking users to put their completed questionnaires in the box. Every 15 minutes returned questionnaires were removed from the box; an immediate transcription was made on 5" x 3" cards of all titles noted in response to question 6 ("Please list the author, title and class-mark, if known, of the long loan books, journals, etc. that you were not able to borrow or consult"). As quickly as possible the exact physical location of these items was ascertained. Although it had not seemed possible to establish the location of items at the actual time that they could not be found, the method adopted did establish the location within a few minutes of the readers leaving the library.

As a second check another method of measuring unrecorded use was also adopted. Notices were liberally distributed over all tables and carrels instructing readers NOT to replace any books on the shelves, and all library staff were instructed not to reshelve any books during the day. Early next morning, before the library opened, a count was made of all books not on the shelves. A count of the number of books issued forms a normal part of the service desk routine; this was used to provide a check on the extent to which the replies were representative of usage on that day.

UNIVERSITY OF LANCASTER

LIBRARY SURVEY

Last year the University Library began a Government-sponsored research project on the efficient management of library services. This questionnaire is being given out because we need some information which we cannot collect in any other way. Please cooperate by answering the questions carefully and so HELP THE LIBRARY TO HELP YOU. Accurate information will be very useful to us in trying to make our service better for you.

QUESTIONNAIRE

It is ESSENTIAL to give NUMERICAL answers relating ONLY to THIS VISIT to the Library, however untypical of your normal behaviour it may be.

1. How many books, journals, etc. did you bring with you to use in the library on this visit? ☐

SHORT LOAN BOOKS

2. How many Short Loan books did you borrow on this visit? ☐

3. How many Short Loan books which you wished to borrow were you not able to obtain on this visit? ☐

Please list the author, title and classmark, if known, of the Short Loan books which you were not able to borrow:

	Author	Title	Classmark (if known)
1.	----------	----------	----------
2.	----------	----------	----------
3.	----------	----------	----------
4.	----------	----------	----------
5.	----------	----------	----------
6.	----------	----------	----------

LONG LOAN BOOKS, JOURNALS etc.

4. How many long loan books, journals, etc. did you borrow on this visit? ☐
[N.B. "Borrowed", in this context, means "issued at the service desk, normally for use outside the Library."]

Fig. 5·1

5. How many long loan or 'reference only' books, journals, etc. did you consult during this visit but not borrow? ☐
[N.B. "Consult", in this context means "use within the Library", but please include any photocopies you asked to have made.]

6. How many long loan books, journals, etc. did you wish to borrow or consult, but were NOT able to obtain during this visit? ☐

Please list the author, title and classmark, if known, of the long loan books, journals, etc. that you were not able to borrow or consult:

	Author	Title	Classmark (if known)
1.	----------	----------	----------
2.	----------	----------	----------
3.	----------	----------	----------
4.	----------	----------	----------
5.	----------	----------	----------
6.	----------	----------	----------
7.	----------	----------	----------
8.	----------	----------	----------
9.	----------	----------	----------
10.	----------	----------	----------

7. What is your status? (Please tick the appropriate box)
1. Undergraduate 1st year ☐
2. Undergraduate 2nd year ☐
3. Undergraduate 3rd year ☐
4. Postgraduate ☐
5. Member of academic staff ☐
6. Other: please specify ----------

8. Please state:
If UNDERGRADUATE: Major or intended major: ----------
If POSTGRADUATE: Department ---------- Degree sought -----
If ACADEMIC STAFF: Department ----------

Thank you for your cooperation.

A.G. Mackenzie
Librarian

PLEASE PUT THE COMPLETED QUESTIONNAIRE IN THE BOX PROVIDED AS YOU LEAVE

Fig 5-1 (contd.)

(i)	Questionnaires handed out	789
	Questionnaires returned	563
	Percentage returned 71	
(ii)	Short Loan issue (actual)	304
	Short Loan issue (questionnaire)	193
	Percentage recorded 63	
(iii)	Long Loan issue (actual)	188
	Long Loan issue (questionnaire)	107
	Percentage recorded 57	

The three percentages 71, 63 and 57 are in close enough agreement to suggest that the returned questionnaires present a balanced picture. All subsequent data are taken from the questionnaires unless specifically stated to be otherwise.

Failure to find items

The main purpose of the survey had been to assess the relative importance of the factors which prevent readers from finding the material which they want. 165 Long Loan items were recorded as not available in response to question 6: of these 165 items, 33 were unidentifiable from the information recorded; the remaining 132 fall into the following categories:

		Frequency	Titles
1.	On loan	39	38
2.	On shelves	23	18
3.	In use	11	8
4.	On Short Loan shelves	10	10
5.	Missing	9	9
6.	Not owned or on order	9	8
7.	At binding	6	6
8.	On loan but also on Short Loan shelves	6	6
9.	On loan but also Short Loan copy on loan	4	3
10.	On loan but also available in stack	4	2
11.	Missing but replacement on order	3	1
12.	On order: not yet arrived	2	2
13.	Missing but another copy available in stack	1	1
14.	Awaiting photocopying	1	1
15.	Awaiting reshelving	1	1
16.	On loan, another copy at binding	1	1
17.	Kept at service desk	1	1
18.	Exhibit removed during survey	1	1
	Total	132	117

Since these data became available a number of remedial steps have been taken to improve availability: two of these were the direct result of work carried out as part of the research project being described in this report. A major change in loan policies was implemented during the summer of 1969 in order to reduce the number of times that items are out on loan when sought - the biggest single source of frustration; this change is described in Chapter 6. A change was made in binding policies in order to reduce the frustration caused by books being at binding when required: this is described in the next section. Other remedial actions unconnected with the research project include the installation of an anti-

theft device to reduce the number of books which are illegally borrowed, and a re-organisation of the acquisitions department. Perhaps the most striking feature of the data is category 2, the second largest category, in which 23 items were in the correct place on the shelves when checked; similarly a number of items sought on the open shelves had been transferred to the closed access reserve collection, where they were available at the time of search. These two facts suggest poor searching, or possibly inadequate or misleading guiding of the library.

B. A simple cost-benefit approach to domestic binding.

During the early summer of 1968 information was needed on the advantages of establishing a domestic bindery; since the University Grants Committee had expressed doubts about the economics of the intention to develop a bindery within the library instead of relying on commercial binderies. Attention was at first concentrated on the mathematical analyses outlined in chapter 3, and in fact the strategy of establishing a play-off between scattering and obsolescence was originally conceived as a method of establishing to what extent it would be worth paying extra for a faster binding service. Unfortunately detailed information on scattering and obsolescence was not available and the circumstances did not seem to justify the task of collecting it, so a cost-benefit analysis was carried out instead.

The University of Lancaster Library was currently having 6, 000 volumes bound each year by commercial firms at an average cost of 23/- per volume. Enquiries from a number of other British university libraries which have domestic binderies produced little relevant factual information, but suggested that their average unit costs were about 24/-.

Against these higher costs must be set the following expected benefits:

(a) There will be a reduction in fairly senior, as well as junior, staff time in preparing books for dispatch (fewer records, no packing, etc.).

(b) There will be a reduction in the frustration and cost to readers of the delay from the time when a reader requests a book to the time of its return to the shelves from binding - this delay appears to average 5 weeks and may on occasion be 10-12 weeks.

(c) If this delay is not acceptable to the reader, a lesser delay (but also a cost) is incurred by obtaining the required item on interlibrary loan: in real terms this unit cost was estimated as 25/- per volume in 1954 - and is certainly more now. Even the marginal direct cost (staff time, postage, etc.) is probably not less than 10/- per loan. A domestic bindery will avoid most of this interlibrary loan cost.

There appears to be no easy way of costing (a) and (b) with any accuracy, but progress can nevertheless be made.

The Frustration Survey already described in chapter 5.A showed that on one day at the main library alone 6 items then at binding were wanted. This survey had about a two-thirds response, so we can expect the actual number of such items to have been 9: in a full year, allowing for seasonal fluctuations, the total number is unlikely to have been less than 1, 200. Clearly data derived from a series of Frustration Surveys would have been more satisfactory, but it was not practical to collect additional data at this time. Even if the domestic bindery's turn-round time is as high as 4 weeks instead of the commercial 10 weeks, this number would be cut by 60% or 720; the remaining 480 items are on the premises and could therefore be made available quite promptly if they were requested. If only half of the frustrated readers asked for material being bound, then a further 240 requests would be satisfied. This makes a total of 960, but in a domestic bindery it would be possible to allocate selective priorities to heavily-used titles, thus cutting their 'down-time' and increasing the figure of

960. Data collected since have confirmed our conviction that demand is not evenly spread, but varies substantially from one title to another.

As regards interlibrary loans to meet unsatisfied requests, little information is available, but the cost of these could perhaps add up to £100 a year. Bindery equipment costs were taken as £5, 000, to be written off (pessimistically) over ten years - viz. £500 per annum.

We can now conveniently summarize the annual costs.

	Domestic		Commercial	
6, 000 volumes bound	at 24/-	£7, 200	at 23/-	£6, 900
Depreciation on capital		£ 500		-
Additional interlibrary loan expenses		-		£ 100
		£7, 700		£7, 000

This suggests a difference in known costs of £700, but the University Grants Committee has since ruled that the bindery equipment could be included in the grant to furnish the extension to the library; the cost to the university becomes nil and the difference in operating costs becomes only £200.

For the price of £200 the library would reap the following advantages:

1. An additional 1000 or more frustrated requests would be satisfied (at a cost of 4/- each);
2. An expected reduction in staff time and fewer records ((a) above);
3. The period of waiting for documents to return from binding would be greatly reduced ((b above).

Conclusion

Domestic binderies are normally justified on the grounds of their intangible benefits rather than their cheaper costs; on the other hand present methods of financing the university result in a part of the cost not being charged to the library concerned. This crude cost-benefit study seems to help to clarify the issue involved. A submission was made along the lines of this section, and a decision was made to establish a bindery at the University of Lancaster Library on somewhat more objective grounds than would otherwise have been the case.

CHAPTER 6: THE PATHOLOGY OF LIBRARY PROVISION:

PART 2: LOAN POLICIES AND DUPLICATION

The previous chapter was concerned with the factors which frustrate library users when they seek documents belonging to a library. It was shown how these factors were surveyed in an attempt to assess their relative importance, and how this information was used to evaluate the choice of long-term binding policy with respect to its impact on the user as well as to considerations of cost. The present chapter is concerned with the most important single cause of frustration - borrowing. The examination of borrowing habits, lending policies and duplication accounted for at least half of the effort during this project; the results fall into two main sections dealing with a closed-access reserve collection and with the general open-access collection respectively.

A. Duplication and availability in a closed access reserve collection

At an early stage of the project, the investigators attempted to see how far an analytical approach could help evaluate a reserve collection of heavily used material known as the Short Loan Collection. All material known, or expected to be in heavy demand is removed from the open shelves to this collection which is located, on closed access, behind the service desk. A user wanting an item from the collection has to ask for it and, if it is available, a member of the library staff will issue it. With a view to increasing the number of readers who can use each copy, and thus reducing the need for duplication, the loan period is short - normally up to four hours. There are twenty-two loan periods in a week: each weekday has four (morning, afternoon, evening and overnight) and Saturday has two (morning and from noon until Monday morning). At whatever time a book is borrowed, it must be returned or re-borrowed by the end of that loan period.

Four factors were isolated, and the objective of the analysis was to establish a relationship between them. These were:

the number of requests for a given title,
the loan period,
the number of copies, and
the standard of service.

The first two were combined by dividing the former by the latter to give an average request rate per loan period. It was assumed that the Poisson distribution could adequately describe the variations in number of requests in individual loan periods. The standard of service chosen was the proportion of requests which were immediately satisfied. This can conveniently be stated as a percentage.

We define n as the number of copies of a given title and s as the number of requests for it in any single loan period, so that when $o \leq s \leq n$ then s requests are satisfied and when $s>n$ then n requests are satisfied. Since P(s) expresses the probability of s requests being made in a loan period

$$\% \text{ Availability} = \frac{100 \left[\sum_{s=o}^{n} sP(s) + \sum_{s=n+1}^{\infty} nP(s) \right]}{\sum_{s=o}^{\infty} sP(s)} \qquad \text{where} \quad P(s) = \frac{e^{-r} r^{s}}{s!}$$

r is the average request rate, and e is a constant (approximately 2.71828).

We now have a relationship involving the four factors listed above and from it we can calculate the dependence of the availability rate on such factors as the length of the loan period and the number of copies provided.

An availability table derived from this work is reproduced as Table 6.1.

In order to test the assumption that the Poisson distribution could adequately describe the variations in the number of requests for individual loan periods, data were collected relating to both the satisfied and the unsatisfied requests over a period of two weeks. A random sample of 25 titles was examined and the distribution of request frequency was examined. Some patterns emerged more than once; for example, more than one title had been used once in one loan period and not at all in the remaining forty-three. Thirteen different patterns of use emerged: in each case the total number of requests occurring during the fortnight was divided by the number of loan periods during this period of time (44) in order to produce an average request rate per loan period for each title. The Poisson distribution was then used to predict a pattern of requests for each average request rate. Table 6.2. shows the comparison between observed and predicted distributions. The level of agreement is encouraging; for five of the thirteen patterns, representing seventeen of the twenty-five titles, the degree of matching could not have happened by chance more than five times in one hundred. The remaining patterns are not statistically significant, but nevertheless add to the overall impression of an adequate match between theory and practice. In view of this similarity, we feel that the use of the Poisson distribution for this purpose is justified.

In practice it was convenient to collect data on both satisfied and unsatisfied requests, since stamps on the date labels denoted satisfied requests, and the staff were able to note unsatisfied requests on a piece of paper. Nevertheless, it may be noted that the total number of requests can be deduced from the record of satisfied requests alone. When the number of requests is less than the number of copies all requests can be satisfied and the frequency of 0, 1, 2, ..., n-1, requests occurring can be noted. However, when the number of issues equals the number of copies in a loan period we only know that the number of requests in the loan period equals or exceeds the number of copies. Yet if we can assume that the distribution of requests approximates that of the Poisson distribution, we can deduce the request rate most likely to result in the rather incomplete data by finding the value of r which maximises

$$L = \prod_{s=0}^{s=n-1} \left(\frac{e^{-r} r^s}{s!} \right)^{f_s} \cdot \left[1 - \sum_{s=0}^{s=n-1} \frac{e^{-r} r^s}{s!} \right]^{f_n}$$

$$\therefore \log L = \sum_{s=0}^{s=n-1} f_s \log \left(\frac{e^{-r} r^s}{s!} \right) + f_n \log \left(1 - \sum_{s=0}^{s=n-1} \frac{e^{-r} r^s}{s!} \right)$$

A more detailed account of the work described in this section can be found in: M. K. Buckland and I. Woodburn: An analytical study of library book duplication and availability. Information storage and retrieval 5. 1969, pp 69-79. This is a revised version of: M. K. Buckland and I. Woodburn: An analytical approach to duplication and availability. (University of Lancaster Library Occasional Papers, No. 2). 1968.

Fig 6-1 **SHORT LOAN AVAILABILITY TABLE**

Requests per day	Copies provided									Copies required for		
	1	2	3	4	5	6	7	8	9	80%	90%	95%
0.4	95	100								1	1	1
0.5	94	100								1	1	2
0.6	93	100								1	1	2
0.7	92	100								1	1	2
0.8	91	99	100							1	1	2
0.9	90	99	100							1	1	2
1	88	99	100							1	2	2
2	79	97	100							2	2	2
3	70	93	99	100						2	2	3
4	63	90	98	100						2	2	3
5	57	86	96	99	100					2	3	3
6	52	81	94	98	100					2	3	4
7	47	77	92	97	99	100				3	3	4
8	43	73	89	96	99	100				3	4	4
9	40	69	86	95	98	99	100			3	4	4
10	37	65	83	93	98	99	100			3	4	5
12	32	58	78	89	96	98	99	100		4	5	5
14	28	52	72	85	93	97	99	100		4	5	6
16	25	47	66	80	90	95	98	99	100	4	5	6
18	22	43	61	76	86	93	97	98	99	5	6	7
20	20	39	57	71	82	90	95	98	99	5	6	7

This table shows percentage availability in relation to the request rate and the number of copies provided. The numbers have been rounded.

Fig 6-2 - COMPARISON OF OBSERVED AND PREDICTED REQUEST PATTERNS

R = No. of requests. O = Observed frequency. P = Frequency predicted by the Poisson distribution.

R	O	P	O	P	O	P	O	P	O	P
0	15	14.12	23	24.37	26	28.57	29	29.90	35	33.50
1	13	16.05	16	14.40	17	12.34	13	11.55	7	9.14
2	11	9.12	5	4.25	1	2.66	2	2.23	1	1.25
3	5	3.45	0	0.84	0	0.38	0	0.29	1	0.11
4	0	0.98	0	0.12	0	0.04	0	0.03	0	0.008
5	0	0.22	0	0.01	-	-	-	-	-	-
6	0	0.04	-	-	-	-	-	-	-	-
7	0	0.007	-	-	-	-	-	-	-	-
		Chi-sq: 2.967		Chi-sq: 1.362		Chi-sq: 3.457		Chi-sq: 0.548		Chi-sq: 7.566
		DF: 7		DF: 5		DF: 4		DF: 4		DF: 4
0	31	32.74	33	32.74	34	35.05	40	40.18	37	35.86
1	13	9.67	9	9.67	10	7.97	4	3.65	5	7.34
2	0	1.43	2	1.43	0	0.90	0	0.17	2	0.75
3	0	0.14	0	0.14	0	0.07	0	0.005	0	0.05
4	0	0.01	0	0.01	-	-	-	-	-	-
		Chi-sq: 2.816		Chi-sq: 0.428		Chi-sq: 1.524		Chi.sq: 0.205		Chi-sq: 2.913
		DF: 4		DF: 4		DF: 3		DF: 3		DF: 3
0	43	43.01	42	42.04	42	41.10				
1	1	0.98	2	1.91	1	2.80				
2	0	0.01	0	0.04	1	0.10				
		Chi-sq: 0.012		Chi-sq: 0.048		Chi-sq: 9.742				
		DF: 2		DF: 2		DF: 2				

Models based on the theory of queues were also developed to represent certain characteristics of the open-access collection. In particular, the effect on immediate availability of allowing borrowing of books normally confined to the library was examined: a tentative model, given below, relates availability for reference only, a loan policy, and a level-of-demand factor, to the loss of availability resulting from allowing borrowing.

$$\% L = \frac{100\,(1-P_r)\,\beta}{P_r\,\alpha}$$

where $\beta = \frac{\lambda_b}{\lambda_r}$

and $\alpha = \frac{\mu_b}{\mu_r}$

L = percentage loss in immediate availability

P_r = probability that a book is available when a demand is made (reference only)

$\lambda_b : \lambda_r$ = arrival rate - borrowing; reference

$\mu_b : \mu_r$ = service rate - borrowing; reference

This model is based on the assumption of negative exponential inter-arrival and servicing times, and a somewhat cavalier summation of the distributions representing borrowing and reference activities.

The general conclusion is that, although analysis gives insight into certain aspects of loan and duplication policy, the Monte Carlo method is a more appropriate technique for handling the complexity of real library systems.

B. Loan policies, duplication and availability

(i) Introduction

In the previous section we were concerned with a rather special case: a closed-access reserve collection of heavily used material with fixed loan periods, where the interest was primarily in determining the number of copies to provide.

In this section we are concerned with the much more complex and much more important problem of determining loan policies in a general open-access collection. Such a collection normally differs from a short loan reserve collection in at least three ways:

a. Data on in-library use and unsatisfied requests are difficult to collect;

b. The large numbers of titles and the low levels of demand suggest a concentration on loan policies rather than duplication as a means of influencing availability;

c. The very wide range in the length of time that a book may be in use (either on loan or within the library), from a few seconds to several months.

Every library has a loan policy, even if that policy is that no books may be borrowed. Libraries which do lend have widely varying loan periods, from two hours to a year or more. Most libraries, especially university libraries, operate a number of loan policies

simultaneously, based on a variety of factors including the type of document, its value, its popularity and the status of the borrower. For example, in the University of Sussex there are five loan periods:

i. Some material is confined to the library;

ii. Some material is placed in a closed-access 'Short Loan' reserve collection and may be borrowed for up to four hours or overnight; this is very similar to the collection described in the previous section;

iii. Some material may be borrowed for up to two days;

iv. Undergraduates may borrow all other material for two weeks;

v. Postgraduates and teaching staff may borrow all other material until the end of term.

Likewise, there is much variation in the regulations concerning renewals, reservations and recalls, in the maximum number of books that may be on loan to any one borrower at any one time and in the sanctions imposed upon borrowers who break the regulations. These variations exist between libraries and often within libraries. Not only is there wide variation, but changes are frequently made. In spite of these facts, and of the central importance of loan policies to the user, the problem of choosing loan policies has been curiously neglected in the professional literature.

(ii) The factors involved

The main purpose of a library is to make books (and other documents) available for the clientèle it serves. Unfortunately 'availability' is a rather complex concept, and considerations of economy and of the convenience of the user lead to a tangle of conflicting objectives. These can conveniently be examined by considering the various aspects of a library's loan policy.

Loan period

The longer the loan period the more convenient it is for the borrower to use the book at leisure. However, the longer the time a book stays out on loan, the longer it is off the shelf and, thereby, the less immediately available it is for other library users. There is a clear conflict here between the convenience of the individual borrower and the convenience of other library users who might wish to use the book. The chances that another reader will in fact wish to use the book when it is out will depend upon the level of demand for the book. It would obviously cause inconvenience if a book sought daily were to go out on loan for weeks at a time; on the other hand, if a book is rarely used (once in a decade, say) then the chances of another user simultaneously wanting it are small, and a longer loan period can be permitted. Not only do books vary greatly in popularity, but the popularity of individual books is liable to fluctuate, although a general tendency for it to decline with time is well established.

Renewal of loan

If a reader wishes to retain a book on loan after the expiry of the original loan period, then it is normal practice to permit one, two or even unlimited renewals unless another reader has made a reservation for that particular book. The frequency of renewal is important: the length of time that a book is absent from the shelves determines "immediate availability" rather than the official loan period.

Reservation and recall

If a book is not on the shelf it can still be made available by means of a reservation and, if appropriate, by recalling it from the reader who has it. To the extent to which this is an acceptable substitute for availability on the shelf, this arrangement reduces the importance of 'immediate availability' and thereby permits longer loan periods and less duplication.

Acceptability apart, this procedure of reservation is clearly unsuitable for those who are not seeking a specific title but are browsing, perhaps purposefully for informationon a specific topic, or less purposefully for inspiration or amusement. If such a reader is browsing along the shelves, then it is clearly important that material should be on the shelves, else the reader will remain unaware of its existence and the provision of a mechanism for reservation and recall will be irrelevant. If such a reader browses in a catalogue or bibliography, then he will presumably identify particular items which he desires to inspect and his search becomes specific. In this case reservation and recall facilities become meaningful, but inspection of catalogue entries is less informative than inspection of the actual document, and there is a body of evidence to suggest that catalogues are not often used in this mode.

Duplication

So far we have been concerned with the case where there is a single copy of each different book, and with the effect of loan policies on the convenience of the users with respect to that book. Obviously, there is no need to enforce a short loan period to induce borrowers to return a book for the benefit of others if sufficient extra copies are in fact available for them. Therefore shortening of the loan period and duplication are alternative methods of increasing the availability of books in libraries. It must be stressed, however, that these alternatives differ in some important respects. The acquisition, processing, and storage of each additional copy of a book costs money and labour which could well be put to other uses, such as another different book or any other library service, and to this extent duplication is undesirable. Reduction of the loan period and the restrictions on renewals, however, are likely to cause additional inconvenience to the borrower, and to this extent are undesirable. Furthermore, the shortening of loan periods is likely to involve additional administrative expenditure.

Administration

Apart from considerations of availability and the cost of duplication, the cost of administering a loan policy must also be considered. A short loan period might be expected to result in a larger number of renewals. A low level of immediate availability (whether by long loan periods or limitation of duplication) is likely to be associated with a larger number of reservations and recalls. A policy decision to maintain a borrowers' file, either as a service to readers or as a means of enforcing a limitation on borrowing, will also involve additional expenditure, as will distinctions between borrowers and especially between books (e.g. when the more popular books are treated differently from less popular ones).

A recent trend in British university libraries towards the "until the end of term" type of loan policy seems to have been at least partly the result of a need to economise on service desk staff by avoiding the necessity for a file arranged by date and by reducing the number of renewals. However, although the loan policies will affect the number of transactions of various kinds, the unit cost will depend very much on the details of the issue system employed, which is outside the scope of this report.

Status of borrower

In some libraries the chosen loan policies give privileges to some users - not just in exceptional circumstances, but as a normal practice. In university libraries, for example, teaching staff almost invariably benefit from a longer loan period and a higher limitation on the number of books allowed out at any given time. One explanation of this is that books used by students are in heavy demand and that a shorter period of loan is therefore thought more appropriate. Another is that teaching staff are more important.

Fines

The principal method of enforcing loan policies is by charging fines, which also vary considerably from library to library. The assumption is that fines are necessary to ensure compliance with regulations; unfortunately, the relationship between fines and borrower behaviour has not, as far as we are aware, been the subject of serious investigation and hence this assumption must remain doubtful.

Summary

It will be clear from the preceding sections that wide variations in loan and duplication policies reflect complicated relationships involving a number of conflicting objectives. Any rational loan policy must be a considered compromise.

(iii) The basic relationship

A single title

The most convenient measure of the availability of a library book is the proportion of times that it is immediately available on the shelf when sought. This can be expressed as a percentage, thus:

$$\% \text{ immediate availability} = \frac{\text{no. of times immediately available when sought} \times 100}{\text{no. of times sought}}$$

Apart from the number of copies held, the two critical factors determining the immediate availability are:

(i) the frequency with which the book is sought (its 'popularity'); and

(ii) the length of time it is off the shelves when in use.

For any given level of demand, the book will become more often available if users can be induced to return it to the shelves more quickly. This is one justification for 'reference' libraries where no borrowing is permitted so that the time a book is absent from the shelves is a matter of hours rather than days or weeks. For any given pattern of return times (the length of time the book is off the shelf) the availability will depend upon the level of demand: a rarely requested book is more likely to be available when sought than a book which is frequently requested.

Obviously the number of copies held is also very important in determining whether a copy will be available when sought. The chances of an unsuccessful library user making a reservation is also important, because a reservation will delay the book's return to the

shelves.

Monte Carlo simulation

In exploring these relationships we have used a technique known as Monte Carlo simulation. Other workers have employed queuing theory and other stochastic process models; for an extended discussion of the application of these formulae to library problems (especially loan policies and duplication) reference should be made to the recent book by P. M. Morse entitled Library effectiveness: a systems approach. (174)

The simulation approach has certain advantages over the more strictly mathematical treatments: for example, it allows greater freedom in the assumptions that can be made, and hence has greater facility in handling complex relationships. A description of the borrowing process is fed into the computer (the description currently in use is shown in Figure 6. 3); in addition, some numerical data are also required, which define, for example, the number of copies, the ratio of borrowing to reference (in-library) use, and the probability that an unsatisfied user will make a reservation. The computer performs the borrowing process several thousands of times, keeps a record of significant events, and then reports the result.

In real life, accurate predictions are often not possible: for example, it is not possible to state with confidence whether the next reader will use a book in the library or borrow it; also it is not possible to state in advance precisely how soon the book will be returned to the shelves. However, data can be collected which shows what the overall pattern is in the long run; similarly, the computer determines such problems by picking numbers at random, as if by rolling dice (hence the name Monte Carlo simulation). Each possible number will have had a particular answer associated with it, and this association of numbers and answers will have been pre-arranged so that in the long term the overall pattern will correspond to the overall pattern of the system being simulated.

In this manner it is possible to simulate situations of great complexity so long as the situation can be described in logical and probabilistic terms. In order to assess the effect of a change in a situation, a simulation of the actual current situation is designed and carried out; the results will, if the simulation is valid, correspond to the actual current results. Another simulation is then performed incorporating the proposed change, and the results indicate in detail the likely consequences of the proposed change. An important feature of this technqiue is that it is possible to examine how sensitive the system being simulated is to particular changes. (For a fuller description of Monte Carlo simulation the interested reader should refer to the appropriate textbooks, such as K. D. Tocher: The art of simulation. (268)) Before describing in detail the results of our simulations, two other relationships need to be examined.

The relationship between actual length of loan and official loan period

Regulations concerning loan periods are, in effect, a control device at the disposal of the librarian (or his committee) for influencing the movement and thereby the availability of the books in his charge. It would therefore seem important to examine the nature of this influence.

At first sight the factors which seem likely to affect the length of time for which a book is retained are both numerous and varied: the subject, the level and the type of the book; the subject background, the work habits and the motivation of the borrower; the thousand and one possible distractions which might affect his behaviour (including recall notices); and the official loan period. In a situation where the factors involved are of such complexity, one

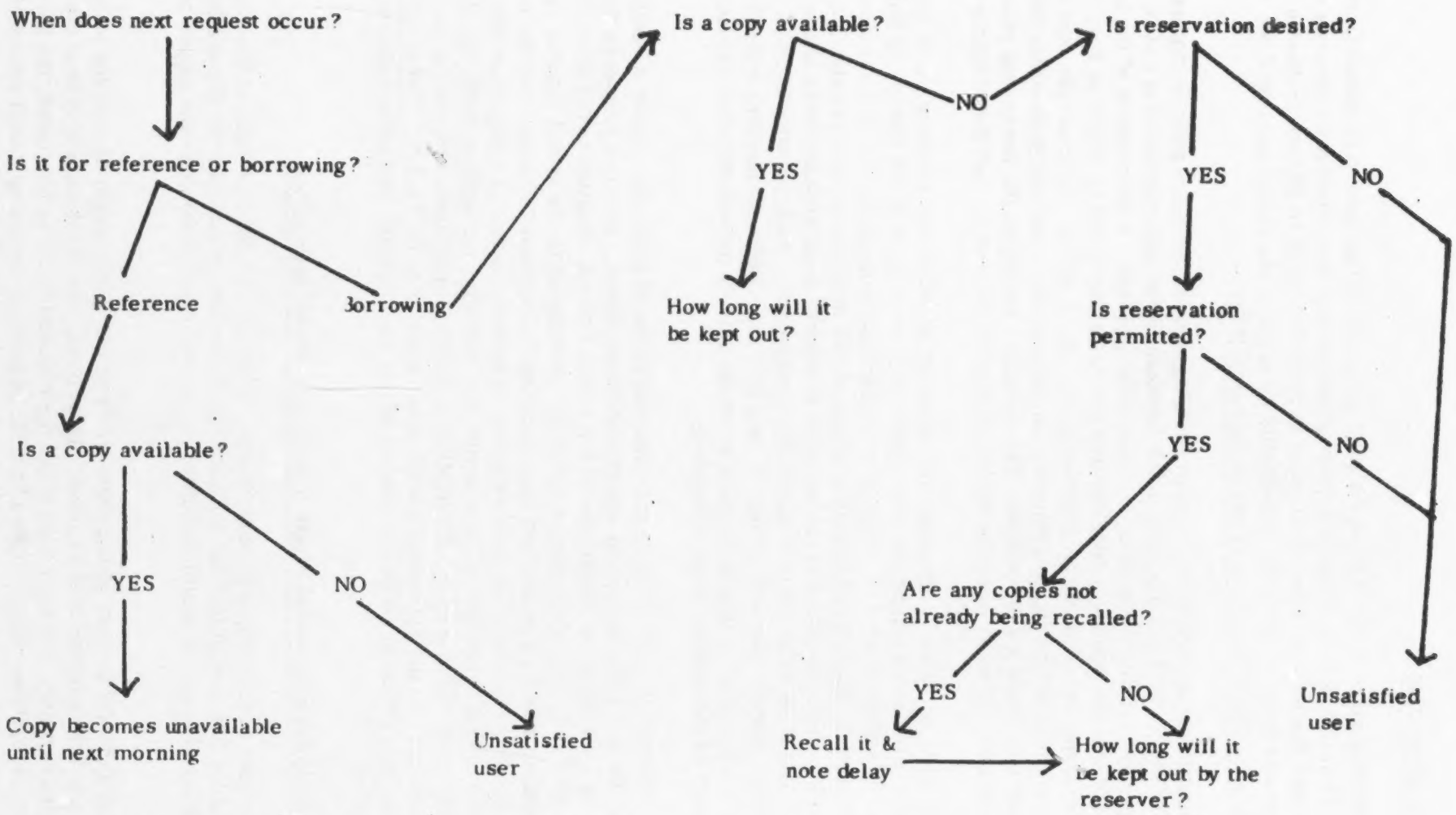


FIGURE 6-3 Description of the borrowing process

would expect books to be returned as if at random - of all books borrowed on a given day a small percentage of those still out being returned each day - with perhaps a small peak at the expiry of the loan period. In order to test this hypothesis, data relating to a variety of loan policies in a number of university libraries were examined as follows:

One week	Manchester
Two weeks	Michigan (33), Strathclyde, Sussex
Four weeks	Manchester, Michigan (33), Strathclyde
Ten weeks	Strathclyde
End of term	Lancaster) An entire year's discharged issued slips
End of year	Lancaster) permitted a variety of analyses to be made.

At none of these libraries is a limitation on the number of books allowed out rigorously enforced. (We have no information about Michigan in this respect).

The pattern which emerged consistently is that there is a very strong tendency for books to be returned or renewed at the expiry of the official loan period - whatever the length of the loan period may be. Only with comparatively long loan periods - longer than four weeks - is a substantial amount of material returned before the due date, and here the expected negative exponential pattern emerges. (See Figure 6.4).

Loan periods and renewals

A further analysis was made to see whether shorter loan periods were associated with increased renewals. The results (Table 6.5) show that the proportion of books renewed one or more times varies little over a range of loan periods. With two exceptions the methods of renewal appear to be comparable - the reader presents the book at the Service Desk and requests a renewal. The two exceptions are the cases of teaching staff at Manchester, where loans are automatically renewed on dates determined by the borrower's surname, and undergraduate two-week borrowing at Sussex, where only one renewal is permitted and that requires rather more effort on the user's part.

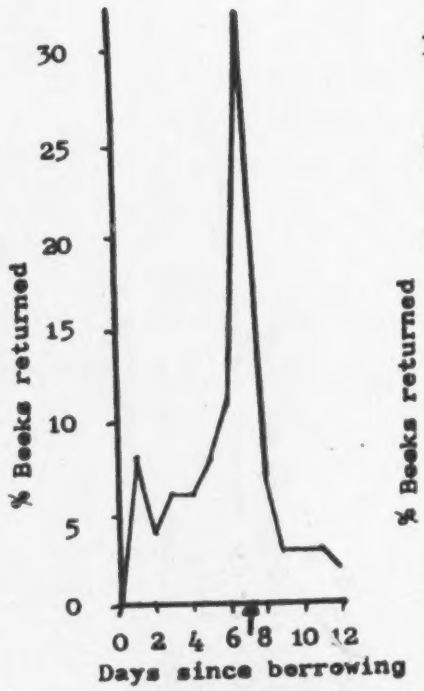
The significance of our findings on the relationships between actual length of loan and official loan period and between renewal patterns and official loan period is considerable. They mean that the librarian has, in his ability to determine official loan periods, a powerful and precise control mechanism for influencing the availability of the books in his library.

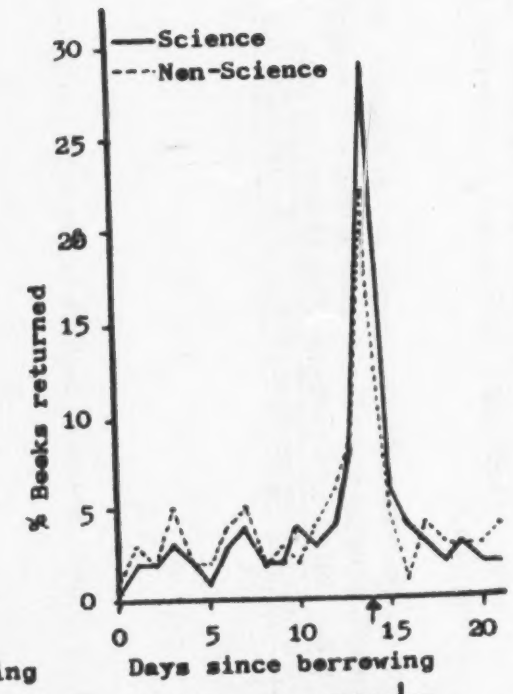
(iv) Application

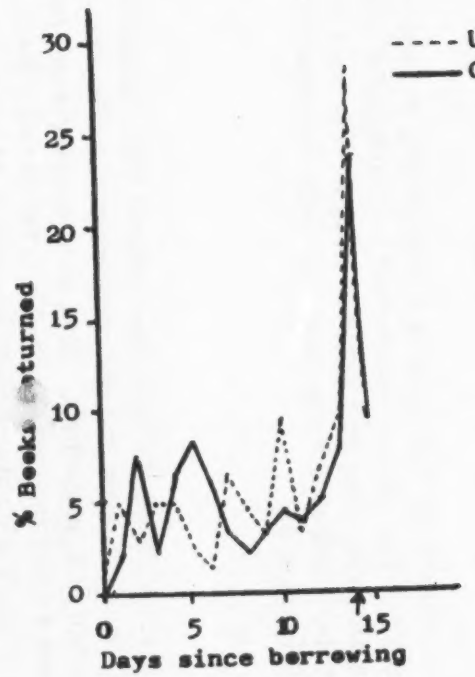
Simulation

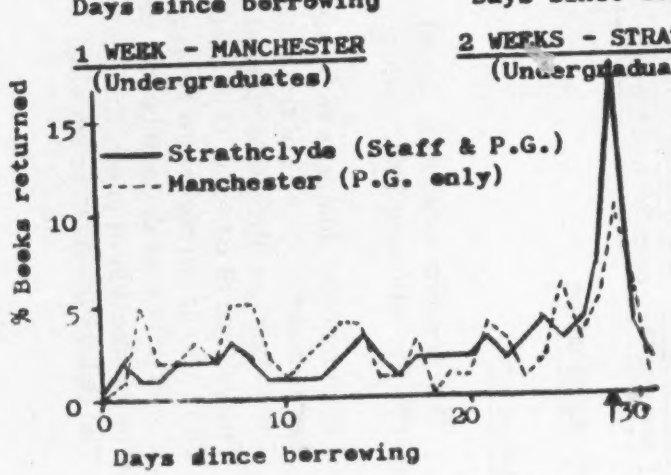
Our present simulation model, outlined above and documented in detail in Appendix A.2, requires the following information:

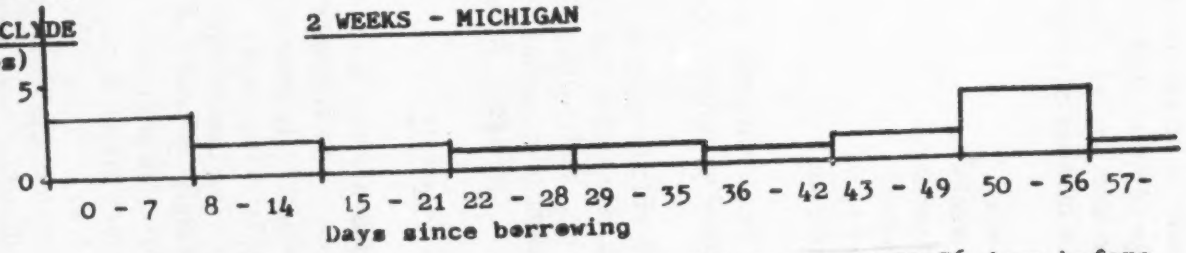
1. The number of demands to be simulated;
2. The number of copies of the book;
3. The maximum allowable number of reservations per book;
4. The pattern of demand as expressed by the intervals between requests;
5. The ratio of borrowing to reference use;
6. A loan policy as defined by the return times;
7. The proportion of unsatisfied users who make reservations;
8. The delays involved in recalls.











8 WEEKS: LANCASTER (Undergraduates): Material borrowed 50-56 days before the date at the end of term when all loans were due back.

FIGURE 6-4 HOW LONG BOOKS ARE KEPT OUT. The number of books (%) returned on successive days since they were borrowed. Data from Manchester and Strathclyde exclude renewals and items reserved by other readers.

LOAN PERIOD	No. of loans analysed	FREQUENCY OF RENEWAL %					
		0	1	2	3	4	5+
1 WEEK:							
Undergraduates at Manchester	2115	67	19	7	4	1	2
2 WEEKS:							
Undergraduates at Strathclyde							
- Science	888	78	11	3	3	1	2
- Non-Science	1208	83	12	2	1	0.8	0.8
- Combined	2096	81	11	13	2	1	2
4 WEEKS:							
P.G. at Manchester	307	69	17	6	2	2	3
Staff & P.G. at Strathclyde							
- Science	510	70	12	6	4	2	6
- Non-Science	483	81	10	4	5	0.2	0.2
- Combined	993	76	11	5	4	1	3

Fig 6-5 Frequency of renewal in relation to the official loan period. The data from Strathclyde, which excludes journals, was regarded as 'Science' if it had been classified in U.D.C. classes 5 or 6. 'Non-Science' data refers to the remaining classes.

The computer reports the following results:
For reference:
a. The number of reference demands made;
b. The percentage of satisfied reference demands;
For loan:
a. The number of loan demands made;
b. The percentage of satisfied loan demand;
c. The level of immediate availability (i. e. the percentage of demands satisfied immediately);
d. The pattern of delays experienced following reservation.

A random sample of the loanable stock of the University of Lancaster Library (excluding the closed access Short Loan collection of very-heavily-used text books) was then analysed by examining borrowing during 1967-68 as recorded on date-labels. Out of a sample of 876 items, 119 were on loan or missing and could not be found in time; the distribution of the remainder, which lends support to the hypothesis that the library's books are subject to demands approximating the Zipf's law distribution, was as follows:

No. of issues per annum	0	1	2	3	4	5	6	7	8	9	10
Frequency	375	168	103	43	40	15	6	2	1	1	1
%	50	22	14	6	5	2	1	0.4	0.3	0.1	0.1

Analysis of borrowing histories, 1967-68

For simulation experiments six popularity classes were defined (popularity being measured by the number of demands per time period (T)) as follows:

Popularity class	A	B	C	D	E	F
No. of borrowing demands per time period T	$4\frac{1}{2}+$	$3\frac{1}{2}-4\frac{1}{2}$	$2\frac{1}{2}-3\frac{1}{2}$	$1\frac{1}{2}-2\frac{1}{2}$	$\frac{1}{2}-1\frac{1}{2}$	$0-\frac{1}{2}$

By attempting to fit various demand distributions to the borrowing history data the proportion of books in each popularity class was determined, where T is one year for the Lancaster collection. The simulation results gave the immediate availability to be associated with each combination of loan policy and popularity level; subsequent calculations determined various parameters for the collection as a whole (as described below). Figure 6.6 illustrates the results of a particular simulation experiment.

Analysis

In examining this matter more closely three measures of effectiveness were employed.

"Immediate Availability": The probability that a request for a given book will be satisfied immediately, i.e. the probability that a book is on the shelves. This is the measure used in the analysis of the Short Loan closed-access reserve collection described in section 6A.

"Satisfaction level": In a given time period the proportion of demands immediately satisfied. All demands, that is, not just demands for one individual title only. This appears to be the most useful single measure of library effectiveness. It is not the same as mean immediate availability.

POPULARITY CLASS	ONE COPY				TWO COPIES				THREE COPIES			
	Loan Policy				Loan Policy				Loan Policy			
	i	ii	iii	iv	i	ii	iii	iv	i	ii	iii	iv
A	91	79.	52	37	100	98	84	66	100	100	97	86
B	94	86	62	44	100	99	91	77	100	100	99	93
C	98	94	72	56	100	100	97	87	100	100	100	98
D	99	98	82	68	100	100	99	84	100	100	100	100
E	100	100	97	85	100	100	100	100	100	100	100	100

Fig 6·6 Simulation results showing immediate availability (%) for 60 trials: 5 popularity classes A-E x 4 loan policies, i-iv x 3 levels of duplication. The four loan policies correspond approximately to loan periods of one week, two weeks, five weeks and ten weeks respectively.

"Collection Bias". Commonly the most strongly-recommended books are removed to a closed-access reserve collection and many of the other more popular books will be out on loan. Consequently a reader who seeks for material on a given subject is faced by an array which systematically tends towards the least popular, the least recommended and the most shunned material. We define this tendency as a "negative bias", and one convenient measure of it is the proportion of the 10% most popular books which are absent from the shelves.

We consider that, subject to consideration of user convenience, a good library should have a high Satisfaction Level and a low Collection Bias. Beyond this, however, it is very difficult to justify any specific Satisfaction Level or Collection Bias until more is known about the effect of each on the library behaviour of users. Clearly, a reference-only library would rate well on both measures, but this entirely neglects out-of-building use, which is generally regarded as desirable.

Analysis of the simuation results in relation to the University of Lancaster Library resulted in an estimated Satisfaction Level of 60% and an estimated Collection Bias of 45%. These estimates were derived as follows: given that a demand distribution for the library has been estimated, it is possible to calculate the probability that a demand (occurring at random) will be for a book within a particular popularity class. If this probability is multiplied by the immediate availability of the popularity class (obtained from the simulation results), then the product is the probability that the next demand will be for a book within a particular popularity class and that it will be satisfied: the Satisfaction Level for the collection as a whole is the sum of these products for the six popularity classes. The Collection Bias can be calculated directly from the immediate availability of the most popular 10 percent of the collection: it is simply (1 - immediate availability).

A check was made on our calculations by comparing a prediction of the total number of books out on loan at the mid-point of the 1967-68 session (to which all data refer) derived from the above analysis with a separate analysis based on issue records and discharged issue slips. The prediction was that 13% of the monograph stock of the library would be on loan; actual records show that the figure was 12%; this close agreement between prediction and fact strengthened our confidence in our calculations.

The loan simulation was then employed to predict the likely consequences of various different policies. After discussion and further data collection, the Librarian prepared the following paper for a meeting of the University's Library Committee.

Librarian's paper on loan policies

Library Committee 30. iv. 69
Agendum 3
LD/69/14

LOAN POLICIES

1. For some time past many members of the Library staff have felt that its loan policies were not ideal, and in recent months this feeling has been reinforced by various suggestions from other members of the University that the periods of loan, and especially that for undergraduates, should be shortened. Accordingly the research team (Messrs. Buckland and Hindle) was asked to investigate the problem fully and report in time for the meeting of the Library Committee on 30th April. It is easy enough to formulate a new loan policy, but difficult to foresee all the potential effects of a change; detailed calculations must be made, data collected, and comparisons drawn with other institutions which have similar policies; and in the end some kind of value judgement must be made of the benefits expected to result from a given expenditure. The following paragraphs are intended to summarise three alternative procedures, the arguments for and against each, and the reasons for their choice.

2. We have taken two basic measures of library performance: Satisfaction Level, S, defined as the probability that a reader will find on the shelf the book which he is seeking; and Collection Bias, B, defined as that proportion of the most-heavily-used tenth of the library stock which is on loan at a given time (this is some indication of the degree of choice which a user has when seeking library material on a given topic). Both these measures are relevant, in differing ways, to library users, and an ideal solution will give a high level for the first and a low level for the second. The problem is to optimise these levels in relation to operating costs and to a fourth variable, the need for readers to use books for some undefined period of time outside the Library (clearly a reference-only library is the optimum in regard to the first three factors, but entirely neglects out-of-building use).

3. Three possible courses of action are considered:

A: No change

Investigations of the use of long-loan stock show that at present Satisfaction Level = 60%, Bias = 45%. We consider this to be unsatisfactory, but by selective duplication (possibly costing £10, 000 - £15, 000 initially and £2, 000 annually) Satisfaction Level could be raised to about 80% and Bias reduced to 20%, which have been chosen as our immediate target.

B: Staff and graduate students - four periods per year; undergraduates - 2 weeks: renewals allowed

This policy would give considerable improvement over policy A: Satisfaction Level = 73%, Bias = 32%; the cost would be of the order of £1, 000 - £1, 500 per annum, mainly in additional junior staff to handle the greatly increased number of loans.

C: "Popular" books issued for 2 weeks; others for four periods per year, irrespective of borrower: renewals allowed

This gives the most favourable result of the three schemes: Satisfaction Level = 80%, Bias = 21%; the costs are only marginally higher than those of scheme B, and there are compensating advantages, in that the results could be made self-adjusting to any reasonable level by varying the definition of "popular" (see Appendix 1).

[Another scheme, a variation on C, was afterwards added as an amendment:
D: "Very popular" books issued for one week; others for four periods per year, irrespective of borrower: renewals allowed

This policy would aim at selecting the 9% of the stock which is most heavily used, and which generates 70% of borrowing. It would cost slightly less than scheme C, and would reduce the incidence of short-period borrowing for staff. Satisfaction Level = 86% and Bias = 8%.]

4. Pros and cons of the three schemes

Pro	Con
Scheme A	
No change - understood by users No additional cost B and S could both be improved by	Low S and high B Users not content Peak in Desk routine work at term end

selective duplication	Improvements in S and B very expensive
Easier control of book stock (reservations, etc.)	Many reservations
Few renewals	

Scheme B

Simple to understand	Inflexible
Considerable improvement in S	Little change in B
Doesn't materially reduce existing privileges of staff and graduate students	Makes undergraduates less privileged
Reduces peaks at Desk	Costs more than scheme A
Fewer reservations needed than in scheme A (50%)	More renewals
Gives mechanism for reducing loan period for serials	
Gives some information on need for selective duplication	

Scheme C

Gives best values for B and S	Unpopular with more selfish staff and postgraduates, as it removes some of their existing privileges
Treats all readers alike	Difficult to enforce 14 day return for staff
Reduces peaks at Desk	Higher number of overdue notices required
Gives mechanism for reducing loan period for serials	High rate of renewals (25%)
Gives more information on library use and need for selective duplication	
Costs only marginally more than scheme B	
Minimum of reservation required	
Flexible	

5. All three schemes are workable: B and C require (perhaps) two extra juniors at the Desk to handle the more complicated issue records (a date file is essential) and the expected number of overdues, at least until users have adapted to the system.

The major questions remaining, under either scheme B or C, are the exact form of the issue record (a technical decision which need not concern the Committee) and the mechanism for enforcing the changed regulations, especially if scheme C is adopted and teaching staff have to return or renew a proportion of their borrowings after 14 days.

The Committee is invited to discuss the three schemes, and recommend one to Senate.

A. G. Mackenzie

Appendix

Method of identifying "popular" books

a) It is known that (excluding the Short Loan collection) 20% of the Lancaster stock generates 80% of borrowing: this is in line with experience elsewhere, and indeed could almost be guessed from such knowledge as we have of undergraduate needs and habits. Unfortunately, this 20% is also used by staff and postgraduate students, so a decision rule for loan period

based solely on status of borrower will not fully achieve the desired effects; in addition I can see no valid argument for maintaining what is in effect a class distinction between undergraduates and staff - both have equally real and genuine needs, different though these may seem to be in kind.

b) This 20% of book stock would form the "popular" section of the collection under scheme C (whether or not some or all serials should be included is a separate, but related, question). The problem remains of identifying these books.

It has been established that records of past use are the simplest and best available predictors of future use (considerably better than the unaided subjective judgement of either teachers or librarians); we have, in stamped date labels, fairly reliable records of past use which can be easily consulted for each book. The entire stock of monographs could be checked, and different date labels inserted in the "popular" 20%, in about 6 man-weeks (junior staff); the system would be monitored once each term, and the examination and "downgrading" of some proportion of the 20% could take perhaps 2-3 man-weeks of (mainly) junior time. New books would be automatically "popular" until they were downgraded, unless there was initial evidence to the contrary. Service Desk staff would be responsible for upgrading, using evidence of use or reservations; but since the general trend is always in the other direction this is not very time-consuming.

[Amendment. Further reflection indicates that it would be better (and certainly cheaper) to make new books initially "unpopular" unless there were evidence to the contrary.]

c) The dividing line between popular and unpopular books [for Scheme C] would basically be evidence of more than twice the average demand, i.e. four or more demands per year; the system can however be set to achieve other values of Bias and Satisfaction Level by changing this decision rule.

(v) Implementation

The Library Committee decided to adopt policy 3D: that is to say, that "very popular" books should be subject to a one week loan. Serials were to be considered later. Rounding the figures slightly in recognition of the fact they are estimates, the new loan policy at Lancaster University Library is designed to achieve the following:

10% of stock to be subject to one week loan;
70% of issues to be subject to one week loan;
85% Satisfaction Level;
10% of the most popular books absent from the shelves at any given time.

It was based on:

the distribution of demand;
the level of demand;
the size of stock;
the level of duplication; and
the size and role of the Short Loan Collection

which existed in 1967-68.

It is, of course, a longstanding tradition in libraries to restrict the use of heavily used material, and one of the advantages of a variable loan policy of the type adopted is that the library can be adjusted to any reasonable Satisfaction Level or Collection Bias by varying the definitions of popularity employed to determine whether books are placed in one loan category

or another. This can be done without changing the official rules and regulations. Furthermore, with any given definitions, the repeated monitoring will result in the library provision being self-adjusting to any changes in the pattern of demand or in duplication policies.

In practice the only data which are at present available concerning the use of individual documents are the dates on their date labels. It has been shown by Fussler and Simon in their Patterns in the use of books in large research libraries (Chicago University Library, 1961) that records of past use are reliable predictors of future use. Certainly the record of borrowing is an incomplete record of total use, but it is the critically important part so far as availability is concerned. The problem has four parts, which are being tackled at Lancaster as follows:

1. Existing stock. The date labels of the entire loanable stock of monographs were examined and deemed 'popular' unless the recorded use averaged less than once per term since the document reached the library shelves. This resulted in approximately 10% of the books being judged popular, and these were marked on the spine and given a distinctive date label. Books borrowed for the vacation were inspected when they returned; those on the shelves were inspected (and, if necessary, processed) by student labour, paid 3/4d. per 100. Pamphlets and Oversize Pamphlets, being subject to consistently low usage, have not been monitored. The total cost of this operation, for some 70,000 monographs, was about £110, excluding the cost of supervision by a member of the research team.

2. Falling popularity: At intervals, probably annually, the shelves will be inspected and the date labels of volumes marked "seven-day loan" will be inspected; if use has declined the spine marking will be removed and an ordinary date label inserted. At any given time some "seven-day loan" books will be out on loan; these will be assumed to have stayed popular.

3. Rising popularity: This is likely to be only a small problem because of the well-established tendency for the popularity of books to decline with time; consequently repeated checking of the entire stock is likely to prove unjustified. Instead the staff of the Service Desk will be authorized to make any book subject to "seven-day loan". The fact that a reservation has been made for a book is in itself excellent prima facie evidence that a book is in demand: in addition, occasional spot checks will be made on "non-popular" books being returned from loan.

4. New books: Those who recommend titles for purchase will be asked to mark an appropriate box on the suggestion card if they expect a book to be popular; the subject specialists who classify books will also indicate books which are likely to be heavily used. An incorrect prediction either way will be corrected by the regular monitoring of 2. and 3. above.

This is, of course, only one possible way: all this information, except that relating to new books, could readily be produced as the by-product of an automated issue system: an alternative approach for either manual or automated systems would be to determine the period of loan at the time of issue without having the books processed into pre-determined loan categories. Such a procedure need not necessarily be unduly time-consuming.

Note: A shorter version of the above section was given by Mr. M.K. Buckland and Dr. A. Hindle as a paper entitled "Loan policies, duplication and availability" at a seminar in July 1969. It was published in the proceedings: Planning library services, ed. by A.G. Mackenzie and I.M. Stuart. (University of Lancaster Library Occasional Papers, No. 3). 1969.

The interested reader is also recommended to refer to two works dealing with loan policies and duplication which were published after much of the work reported above had been

completed. These are:

1. P.M. Morse: Library effectiveness: a systems approach. Boston, Mass., M.I.T. Press. 1968.

2. Burkhalter, B.R. & Race, P.A. An analysis of renewals, overdues and factors influencing the optimal chargeout period. In BURKHALTER, B., ed. Case studies in library systems analysis. Metuchen, N.J., Scarecrow Press. 1968. pp 11-33.

CHAPTER 7: CONCLUSIONS: ENVOI

The development of university libraries is being greatly influenced by two powerful forces; firstly, by the colossal growth in the quantity of publication ('the information explosion') and secondly, by the enormous expansion of higher education. Consequently university libraries are growing not only in number but also in size. In this situation it is clearly important to attempt to ensure that the resources at the disposal of the librarian (which include the power to make regulations as well as space, manpower and money) are deployed in a manner which will contribute as effectively as possible to the purposes of the university. It was for this reason that the "Systems analysis of a university library" was undertaken and an attempt was made to explore, analyse and describe key aspects in the provision and use of library services, the rationale being that a better understanding should lead to better planning and management.

This report describes what has been done towards this aim, and how substantial changes have already been made in one library as a direct consequence of the project. Yet although it can be claimed that progress has been made, so also it must be admitted that far more remains to be done. Libraries are in some ways simple things: books are placed on shelves and people come and use them; yet any system involving human beings is bound to be complex. Operational research studies of libraries have in general tended to concentrate on the logistics of providing library services, but the real difficulties in the planning and management of libraries stem from the users of the services, and it is on this side that progress desperately needs to be made if there is to be any pretence at rational librarianship. For example, in chapter 6 it is shown how a shortening of loan periods can be used to increase the immediate availability of books (the probability that it is on the shelf when wanted). However, this will be achieved at the expense of decreased average utilisation (measured by the time a book is off the shelf: "in use") of the items of information. Nevertheless, an examination of the distribution of the lengths of time that a book is kept out ("return times") from various universities suggests a relationship between length of loan period and "idle time" when the book is on the user's shelf waiting to be returned. This is a question of user behaviour: it suggests an inertia factor which needs to be analysed and taken into consideration when decisions are made concerning the shortening or lengthening of loan periods.

Similarly, a problem arises directly from the arguments concerning the importance of increasing the immediate availability of popular books (the probability that they are available on the shelf when wanted). The argument runs as follows: if a user knows precisely what specific book or item of information he requires then, if it is not available immediately, at least he can reserve it and obtain it in a few days. Increasing the level of immediate availability by shortening the loan periods may not be worth the decreased book utilisation which may result, together with the inconvenience (to both library and user) of an earlier expiry of loan period. However, if the user is more vague about the source of the information he requires, he will want to search through the relevant section of the library, with or without the aid of catalogues. If the level of immediate availability is low the selection of items available for the search process will be restricted and, usually, biased in favour of "unpopular" books. Hence the level of immediate availability may be critical for users in this latter low state of specificity of information requirement. Again the probability of a given user's need having a particular degree of specificity needs to be investigated.

Fundamentally related to all this in a university library is the whole area of students' problem-solving behaviour, about which comparatively little appears to be known. Yet the essential role of the library is that of one of a number of information sources designed and provided to assist the members of the university, all of whom have problems in the intellectual and cognitive sense. Until more is known about the problem-solving behaviour of the users and about the library's rôle in providing assistance, it is difficult to assess the

contribution of the library to the university's aims. One survey of an English university library revealed that 26% of the students did not borrow even one book during a year. A number of studies have suggested that there is a correlation between amount of library use and academic achievement: none of them, however, provide evidence that this is a causal relationship. Nevertheless, the fact that the more successful students choose to use the library does suggest that those who do not would benefit academically if they could be encouraged to do so. Towards this end it is necessary to examine the factors which encourage or discourage student use of the library: it might well emerge, for example, that students with comparatively low drive, or with little experience of library use, might tend to use the library less skilfully, and hence less successfully, than others with whom they are in competition for limited book resources. If so, then their attempts to use the library are likely to prove a discouraging experience which they will tend to avoid in future. Indeed, these are good reasons for supposing that less frequent use will tend to lead to less successful use; thus a pattern of decreasing use would be self-reinforcing. If key factors in the initial encounters with the library could be identified, then one or more might prove to be within the influence of the librarian, who would then be able to take appropriate remedial action to encourage library use and thereby, perhaps, increase the overall level of academic achievement.

It is quite clear that the serious study of policy-making and the allocation of resources in a university library must range widely over problems of human behaviour and educational research. Seen in this wider context it may be that the most useful contribution of the "Systems analysis of a university library" project may be not the models presented in earlier chapters, but rather in suggesting ways in which, with further research, it may prove possible quantitatively to relate day-to-day decisions by the librarian to the academic achievement of the university as a whole.

APPENDIX A : PROGRAM DOCUMENTATION

Prepared by Mr. M.Dobson.

A.1. PROGRAM DOCUMENTATION OF BOOK PROCESSING MODEL

The Program - #WLUL

The program depicts a mathematical model of a typical University Library acquisition system. Books arriving from various sources are seen to pass through various processes such as cataloguing (and possibly binding) until they finally arrive on the shelves.

The program distinguishes up to 15 different phases of the system. An individual book passes through several of these phases but never all of them. Output consists of a detailed listing of work achieved at the various phases during the weeks the system is investigated together with indications of delays occurring at various phases.

Documentation included to assist in understanding of the program is: -
(a) Data requirements of #WLUL
(b) Detailed flowchart of #WLUL
(c) Listing of #WLUL

A mathematical description of the model and an outline flowchart are contained in chapter 2.

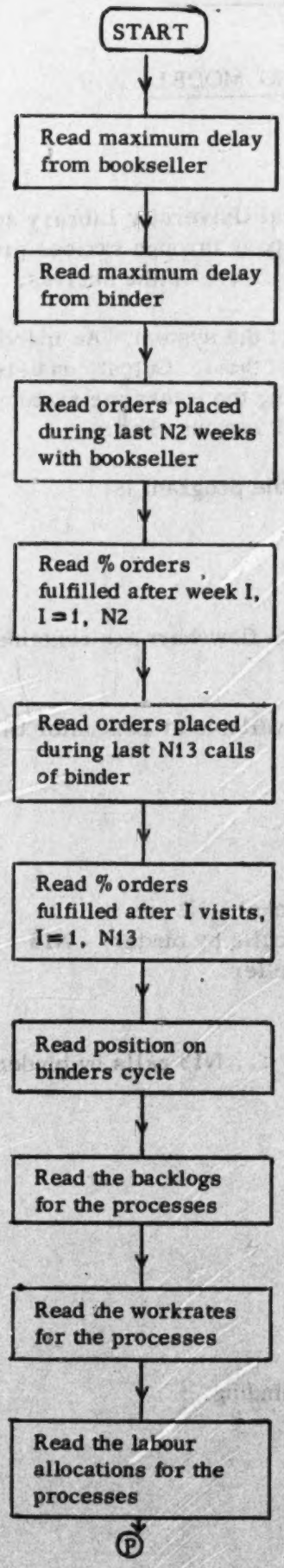
#WLUL is written in ALGØL and on the ICL '1905' available at Lancaster University compiles to 4544 words.

(a) #WLUL - Data requirements

All data is punched in 'algol-readable' form.

1) Maximum delay for books ordered via bookseller (in weeks) - N2
2) Maximum delay for books sent to binder for binding (in calls by binder) - N13
3) Orders for books placed during last N2 weeks via bookseller.
4) Proportion of orders fulfilled after 1, 2, ... N2 weeks.
5) Books sent for binding during last N13 calls by binder.
6) Proportion of books sent for binding returned after 1, 2, ... N13 calls by binder.
7) Position on binder cycle.
8) Backlogs for the 15 processes.
9) Work rates for the 15 processes.
10) Labour allocation for the 15 processes.
11) For each week:
    (i) number of titles suggested
    (ii) proportions of suggestions not ordered
    (iii) number of donations received
    (iv) number of books bought via bulk purchases
    (v) proportion of books needing only brieflisting
    (vi) proportion of books processed this week needing binding.

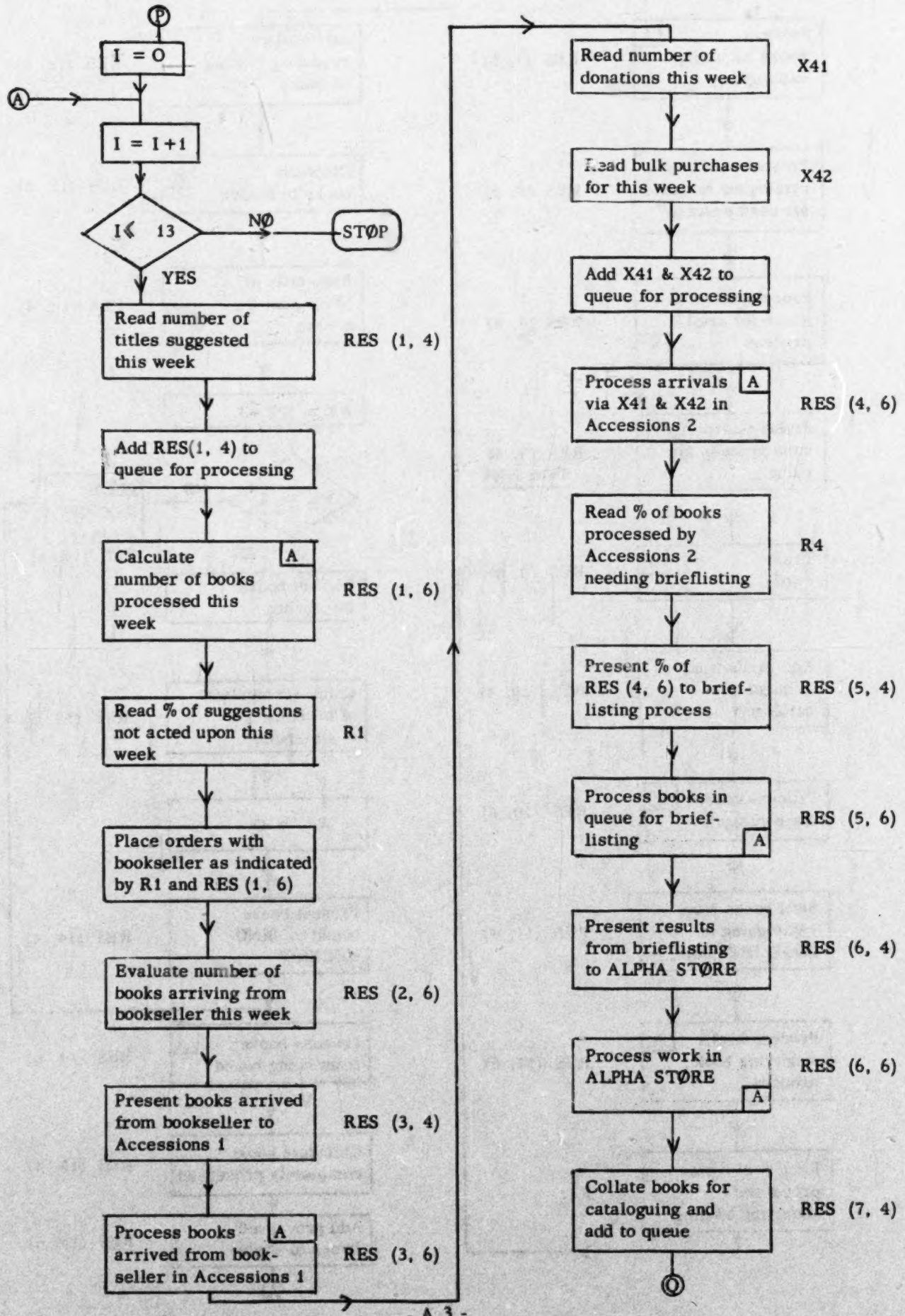
(b) Detailed Flowchart of #WLUL


START
Read maximum delay from bookseller
N2
Read maximum delay from binder
N13
Read orders placed during last N2 weeks with bookseller
ØBK (Row 1)
Read % orders fulfilled after week I, I=1, N2
ØBK (Row 2)
Read orders placed during last N13 calls of binder
BIND (Row 1)
Read % orders fulfilled after I visits, I=1, N13
BIND (Row 2)
Read position on binders cycle
WK
Read the backlogs for the processes
RES (Column 1)
Read the workrates for the processes
RES (Column 2)
Read the labour allocations for the processes
RES (Column 3)
P

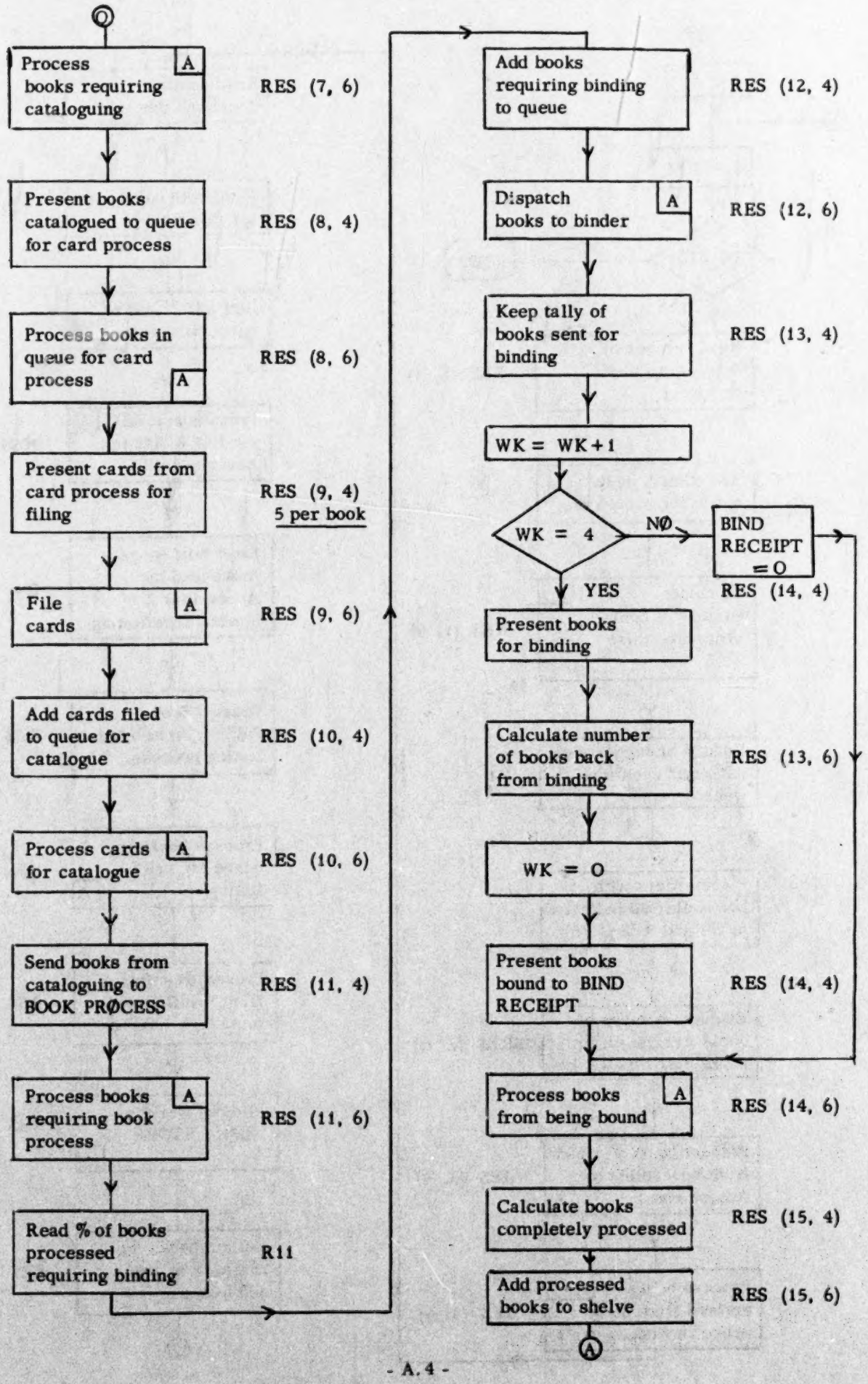
Process involved in 'A' boxes

Two figures are evaluated: output from process and delay incurred in passing through the process. Output is the smaller of the capacity of the process and work needing to be done. Delay is backlog at end of work divided by capacity per week giving delay incurred in weeks.

The figures alongside the boxes indicate where the data is stored in the program.


P
I = O
A
I = I+1
I < 13
NØ
STØP
YES
Read number of titles suggested this week
RES (1, 4)
Add RES(1, 4) to queue for processing
Calculate number of books processed this week
A
RES (1, 6)
Read % of suggestions not acted upon this week
R1
Place orders with bookseller as indicated by R1 and RES (1, 6)
Evaluate number of books arriving from bookseller this week
RES (2, 6)
Present books arrived from bookseller to Accessions 1
RES (3, 4)
Process books arrived from book-seller in Accessions 1
A
RES (3, 6)
Read number of donations this week
X41
Read bulk purchases for this week
X42
Add X41 & X42 to queue for processing
Process arrivals via X41 & X42 in Accessions 2
A
RES (4, 6)
Read % of books processed by Accessions 2 needing brieflisting
R4
Present % of RES (4, 6) to brief-listing process
RES (5, 4)
Process books in queue for brief-listing
A
RES (5, 6)
Present results from brieflisting to ALPHA STØRE
RES (6, 4)
Process work in ALPHA STØRE
A
RES (6, 6)
Collate books for cataloguing and add to queue
RES (7, 4)
Q

- A.3 -


Process books requiring cataloguing A
RES (7, 6)
Present books catalogued to queue for card process
RES (8, 4)
Process books in queue for card process A
RES (8, 6)
Present cards from card process for filing
RES (9, 4)
5 per book
File cards A
RES (9, 6)
Add cards filed to queue for catalogue
RES (10, 4)
Process cards for catalogue A
RES (10, 6)
Send books from cataloguing to BOOK PRØCESS
RES (11, 4)
Process books requiring book process A
RES (11, 6)
Read % of books processed requiring binding
R11
Add books requiring binding to queue
RES (12, 4)
Dispatch books to binder A
RES (12, 6)
Keep tally of books sent for binding
RES (13, 4)
WK = WK+1
WK = 4
NØ
BIND RECEIPT = O
RES (14, 4)
YES
Present books for binding
Calculate number of books back from binding
RES (13, 6)
WK = O
Present books bound to BIND RECEIPT
RES (14, 4)
Process books from being bound A
RES (14, 6)
Calculate books completely processed
RES (15, 4)
Add processed books to shelve
RES (15, 6)
A

(c) LISTING OF #WLUL

```
15/07/45        31/05/67        COMPILED BY XALM MK. 11A
ST=     0 !!!   'LIST'(LP)
ST=     0 !!!   'RUN'
ST=     0 !!!   'PROGRAM'(WLUL)
ST=     0 !!!   'INPUT'  0 = TR0
ST=     0 !!!   'OUTPUT' 0 = LP0
ST=     0 !!!   'SPACE'  500
ST=     0 !!!   'TRACE'  2
ST=     0 !!!
ST=     0 !!!
ST=     0 !!!   'BEGIN' 'INTEGER' N2, N13;
ST=     1 !!!           .
ST=     1 !!!   'COMMENT' MAXIMUM DELAYS FOR BOOKSELLER AND BINDER;
ST=     1 !!!
ST=     1 !!!   N2 := READ;  N13 := READ;
ST=     4 !!!
ST=     4 !!!         'BEGIN' 'INTEGER' T, DEP, I, MK;
ST=     4 !!!         'REAL' 'ARRAY' ORK[1:2, 1:N2], BINDC[1:2, 1:N13], RESC[1:15, 1:7];
ST=     5 !!!         'REAL' R1, X41, X42, R4, Y42, R11;
ST=     6 !!!
ST=     6 !!!
ST=     6 !!!         'COMMENT' THE STATE OF THE LIBRARY AT ANY TIME T IS REPRESENTED BY THE ARRAY
ST=     6 !!!               RES, WHICH HAS A ROW FOR EACH OF FIFTEEN DEPARTMENTS.  MOST OF THESE
ST=     6 !!!               HAVE SEVEN CHARACTERISTICS, WHICH ARE UPDATED BY THE PROCEDURE CTG ONE.
ST=     6 !!!               COUNTERS DEP AND I ARE USED TO SCAN RES.
ST=     6 !!!                  THE EXCEPTIONS ARE THE BOOKSELLER AND THE BINDER, WHICH ARE MODELLED
ST=     6 !!!               BY THE PROCEDURE BOOKSHOP.  PAST ORDERS ARE RECORDED IN THE ARRAYS ORK AND
ST=     6 !!!               BIND, TOGETHER WITH THE PROPORTIONS OF AN ORDER DELIVERED AFTER A GIVEN
ST=     6 !!!               PERIOD.  THESE ARRAYS ARE FILLED INITIALLY BY THE PROCEDURE OPEN SHOP.  IN
ST=     6 !!!               ADDITION, THE BINDER ONLY CALLS EVERY FOURTH WEEK, COUNTED ON THE COUNTER MK.
ST=     6 !!!                  R1 IS THE PROPORTION OF BOOK SUGGESTIONS NOT ORDERED, X41 AND X42 ARE
ST=     6 !!!               DONATIONS AND BULK PURCHASES, OF WHICH A PROPORTION R4 ARE ONLY
ST=     6 !!!               BRIEFLISTED, LEAVING Y42 TO GO STRAIGHT TO CATALOGUING, AND R11 IS
ST=     6 !!!               THE PROPORTION OF BOOKS THAT REQUIRE BINDING;
ST=     6 !!!
ST=     6 !!!
ST=     6 !!!         'PROCEDURE' CTG ONE(D, RS);
ST=     7 !!!               'VALUE' D; 'INTEGER' D; 'REAL' 'ARRAY' RS;
ST=    10 !!!               'BEGIN'
ST=    11 !!!
ST=    11 !!!                  'PROCEDURE' TYPE ONE(L, W, B, X, P, Y, D);
ST=    11 !!!                     'VALUE' L, W, X; 'REAL' L, W, B, X, P, Y, D;
ST=    13 !!!
ST=    13 !!!                        'COMMENT' LABOUR, WORK-RATE, BACKLOG, INPUT, PROCESSING CAPACITY,
ST=    13 !!!                           OUTPUT, AND DELAY TO A NEW ITEM, ASSUMING SERIAL PROCESSING;
ST=    13 !!!
ST=    13 !!!                        'BEGIN'
ST=    14 !!!                        P := L*W;
ST=    16 !!!                        Y := 'IF' B+X 'GE' P 'THEN' P 'ELSE' B+X;
ST=    17 !!!                        B := B+X-Y;
ST=    18 !!!                        D := 'IF' P=0 'THEN' -1 'ELSE' B/P
ST=    18 !!!                        'END' TYPE ONE;
ST=    18 !!!
ST=    18 !!!                  TYPE ONE(RSCD,1), RSCD,2), RSCD,3), RSCD,4), RSCD,5), RSCD,6), RSCD,7) )
ST=    19 !!!                  'END' CTG ONE;
ST=    19 !!!
ST=    19 !!!         'PROCEDURE' OPEN SHOP(N, BKSL);
ST=    20 !!!               'VALUE' N; 'INTEGER' N; 'REAL' 'ARRAY' BKSL;
ST=    23 !!!
ST=    23 !!!                  'COMMENT' ROW ONE OF AKSL CONTAINS ORDERS UP TO N WEEKS AGO, AND ROW
ST=    23 !!!                      TWO THE FRACTION OF AN ORDER DELIVERED AFTER I WEEKS;
ST=    23 !!!
ST=    23 !!!                  'BEGIN' 'INTEGER' I;
ST=    24 !!!                  'FOR' I := 1 'STEP' 1 'UNTIL' N 'DO' BKSL[1, I] := READ;
ST=    29 !!!                  'FOR' I := 1 'STEP' 1 'UNTIL' N 'DO' AKSL[2, I] := READ;
ST=    33 !!!                  'END' OPEN SHOP;
ST=    33 !!!
ST=    33 !!!         'PROCEDURE' BOOK SHOP(N, X2, ORK, Y2);
ST=    34 !!!               'VALUE' N, X2; 'INTEGER' N; 'REAL' X2, Y2; 'REAL' 'ARRAY' ORK;
ST=    38 !!!
ST=    38 !!!                  'BEGIN' 'INTEGER' I; 'REAL' Z;
ST=    40 !!!                  'COMMENT' MOVE ORDERS BACK A WEEK, AND FIT IN THE LATEST ONE - I IS 1
ST=    40 !!!                     FOR CURRENT WEEK, N FOR LONGEST OUTSTANDING;
ST=    40 !!!
ST=    40 !!!                  'FOR' I := N 'STEP' -1 'UNTIL' 2 'DO' ORK[1, I] := ORK[1, I-1];
ST=    45 !!!                  ORK[1, 1] := X2;
ST=    46 !!!
ST=    46 !!!                  Z := 0;
ST=    47 !!!                  'FOR' I := 1 'STEP' 1 'UNTIL' N 'DO' Z := Z + ORK[1,I]*ORK[2,I];
ST=    51 !!!                  Y2 := Z
ST=    51 !!!                  'END' BOOK SHOP;
ST=    51 !!!
ST=    51 !!!         'PROCEDURE' DEPT NAME(N);
ST=    52 !!!               'VALUE' N; 'INTEGER' N;
ST=    54 !!!
ST=    54 !!!                  'BEGIN' 'SWITCH' CAPTION := A,B,C,D,E,F,G,H,I,J,K,L,M,N,O;
ST=    55 !!!                  'GO TO' CAPTION[N];  SPACE(12); 'GO TO' Z;
ST=    59 !!!
ST=    59 !!!                  A : WRITE TEXT('('ORDERINGS$$$'')'); 'GO TO' Z;
ST=    62 !!!                  B : WRITE TEXT('('BOOKSELLERS'')'); 'GO TO' Z;
ST=    65 !!!                  C : WRITE TEXT('('ACCESSIONS$1'')'); 'GO TO' Z;
ST=    68 !!!                  D : WRITE TEXT('('ACCESSIONS$2'')'); 'GO TO' Z;
```

```
ST=    71 !!!                E : WRITE TEXT('('BRIEFLISTING')'); '68 T8' Z;
ST=    71 !!!                F : WRITE TEXT('('ALPHA$STORE%')'); '68 T8' Z;
ST=    74 !!!                G : WRITE TEXT('('CATALOGUING%')'); '68 T8' Z;
ST=    77 !!!                H : WRITE TEXT('('CARD$PROCESS')'); '68 T8' Z;
ST=    80 !!!
ST=    83 !!!                I : WRITE TEXT('('CARD$FILING%')'); '68 T8' Z;
ST=    83 !!!                J : WRITE TEXT('('CATALOGUE$$%')'); '68 T8' Z;
ST=    86 !!!                K : WRITE TEXT('('BOOK$PROCESS')'); '68 T8' Z;
ST=    89 !!!                L : WRITE TEXT('('DESP$TO$BIND')'); '68 T8' Z;
ST=    92 !!!
ST=    95 !!!                M : WRITE TEXT('('$$BINDER$$$%')'); '68 T8' Z;
ST=    95 !!!                N : WRITE TEXT('('BIND$RECEIPT')'); '68 T8' Z;
ST=    98 !!!                O : WRITE TEXT('('BOOK$$STOCK%')');
ST=   101 !!!
ST=   103 !!!                Z :
ST=   103 !!!                'END' DEPT NAME;
ST=   103 !!!
ST=   104 !!!
ST=   104 !!!
ST=   104 !!!          'COMMENT' WE HAVE ALREADY READ THE LENGTHS OF THE ORDER BOOKS OF THE BOOK-
ST=   104 !!!                SELLER AND THE BINDER.  NOW WE READ THE INITIAL ORDERS AND FRACTIONS
ST=   104 !!!                DELIVERED, AND THEN HOW LONG IT IS SINCE THE BINDER LAST CALLED.  WK
ST=   104 !!!                SHOULD BE BETWEEN 0 AND 4.  THEN WE READ THE 15 INITIAL BACKLOGS,
ST=   104 !!!                WORK-RATES, AND LABOUR ALLOCATIONS FOR THE DEPARTMENTS;
ST=   104 !!!
ST=   104 !!!          OPEN SHOP(N2, OBK); OPEN SHOP(N13, BIND); WK := READ;
ST=   108 !!!
ST=   108 !!!          'FOR' I := 3 'STEP' -1 'UNTIL' 1 'DO'
ST=   111 !!!                'FOR' DEP := 1 'STEP' 1 'UNTIL' 15 'DO' RESC(DEP, I) := READ;
ST=   115 !!!
ST=   115 !!!          'COMMENT' NOW DRIVE THE MODEL FOR THIRTEEN WEEKS;
ST=   115 !!!          'FOR' T := 1 'STEP' 1 'UNTIL' 13 'DO'
ST=   118 !!!
ST=   118 !!!                'BEGIN' 'COMMENT' READ INPUT SUGGESTIONS, AND PROPORTION NOT ORDERED;
ST=   118 !!!
ST=   118 !!!                RESC(1, 4) := READ; CTB ONE(1, RES);
ST=   121 !!!                R1 := READ; BOOKSHOP(N2, (1-R1)*RESC(1, 6), OBK, RESC(2, 6));
ST=   123 !!!                RESC(3, 4) := RESC(2, 6); CTB ONE(3, RES);
ST=   125 !!!
ST=   125 !!!                'COMMENT' SO MUCH FOR ORDERS VIA BOOK SHOP, NOW READ DONATIONS
ST=   125 !!!                   AND BULK PURCHASES;
ST=   125 !!!
ST=   125 !!!                X41 := READ; X42 := READ; RESC(4, 4) := X41 + X42; CTB ONE(4, RES);
ST=   129 !!!
ST=   129 !!!                'COMMENT' SEND A PROPORTION R4 TO BRIEFLISTING, THE REST STRAIGHT TO
ST=   129 !!!                   FULL CATALOGUING;
ST=   129 !!!
ST=   129 !!!                R4 := READ; RESC(5, 4) := R4*RESC(4, 6); Y42 := RESC(4, 6) - RESC(5, 6);
ST=   132 !!!                CTB ONE(5, RES); RESC(6, 4) := RESC(5, 6); CTB ONE(6, RES);
ST=   135 !!!
ST=   135 !!!                'COMMENT' TWO STREAMS MERGE FOR CATALOGUING;
ST=   135 !!!
ST=   135 !!!                RESC(7, 4) := RESC(3, 6) + RESC(6, 6) + Y42; CTB ONE(7, RES);
ST=   137 !!!
ST=   137 !!!                'COMMENT' TWO OUTPUTS FROM CATALOGUING - CARDS TO FILE, AND BOOKS
ST=   137 !!!                   TO BIND OR SHELVE - FIRST CARDS;
ST=   137 !!!
ST=   137 !!!                RESC(8, 4) := RESC(7, 6); CTB ONE(8, RES);
ST=   139 !!!                RESC(9, 4) := 5*RESC(8, 6); CTB ONE(9, RES);
ST=   141 !!!                RESC(10, 4) := RESC(9, 6); CTB ONE(10, RES);
ST=   143 !!!
ST=   143 !!!                'COMMENT' NOW BOOKS - R11 IS THE PROPORTION TO BE BOUND;
ST=   143 !!!
ST=   143 !!!                RESC(11, 4) := RESC(7, 6); CTB ONE(11, RES);
ST=   145 !!!                R11 := READ; RESC(12, 4) := R11*RESC(11, 6); CTB ONE(12, RES);
ST=   148 !!!
ST=   148 !!!                'COMMENT' BINDER VISITS EVERY 4TH WEEK - ACCUMULATE BOOKS IN BETWEEN;
ST=   148 !!!
ST=   148 !!!                RESC(13, 4) := RESC(13, 4) + RESC(12, 6);
ST=   149 !!!                WK := WK + 1;
ST=   150 !!!                'IF' WK 'GE' 4 'THEN'
ST=   151 !!!                   'BEGIN' BOOKSHOP(N13, RESC(13, 4), BIND, RESC(13, 6));
ST=   153 !!!                   WK := 0; RESC(13, 4) := 0; RESC(14, 4) := RESC(13, 6)
ST=   155 !!!                   'END'
ST=   155 !!!                   'ELSE' RESC(14, 4) := 0;
ST=   157 !!!
ST=   157 !!!                CTB ONE(14, RES);
ST=   158 !!!                RESC(15, 4) := RESC(14, 6) + (1 - R11)*RESC(11, 6); CTB ONE(15, RES);
ST=   160 !!!
ST=   160 !!!                'COMMENT' REPORT THE RESULTS OF THIS WEEK'S WORKING;
ST=   160 !!!
ST=   160 !!!                WRITE TEXT('('  '('C20$')'WOODLAND$$UNIVERSITY$$LIBRARY'('2')'WEEK$!')');
ST=   161 !!!                PRINT(T, 2, 0);
ST=   162 !!!                WRITE TEXT('('  '('C13$')'LABOUR$$W/RATES$$BACKLOGS$INFLOWS$WK/CAPS$
ST=   162 !!!                   OUTPUTS$$DELAY'('2C')'  ')');
ST=   163 !!!
ST=   163 !!!                'FOR' DEP := 1 'STEP' 1 'UNTIL' 15 'DO'
ST=   166 !!!                   'BEGIN' DEPT NAME(DEP);
ST=   168 !!!                   'FOR' I := 1 'STEP' 1 'UNTIL' 7 'DO' PRINT(RESC(DEP, I), 5, 0);
ST=   172 !!!                   NEWLINE(1)
ST=   172 !!!                   'END';
ST=   173 !!!
ST=   173 !!!                NEWLINE(3)
ST=   173 !!!                'END' LOOP ON T
ST=   173 !!!          'END' INNER BLOCK
ST=   173 !!!    'END' PROG;
CORE  4544
COMPILED   #WLUL          EC
```

APPENDIX A.2. PROGRAM DOCUMENTATION OF THE LOAN SIMULATION

LIBSIMO1- The program and its use.

Objective

The objective is to simulate the lending system of a typical library and the flow-diagram below shows the precise model employed.

The user can, by means of several input parameters which will be described later, investigate the performance of the system under varying conditions and so determine the effect of modifications to the system without having to implement them.

The model will give the user greater insight into the functioning of the system and will hopefully pin-point areas for further investigation. An example of its application is described in chapter 6, section B.

Method

The model is time-dependent starting at an assumed simulation clocktime of zero and advancing in discrete intervals of time, each stop occurring when an event is to take place. There are two such time-dependent or primary events considered in the model - a demand for a copy of the book and the return of a copy of the book.

Several events may occur simultaneously including several occurrences of the same event. The simulation terminates when the required number of requests to be simulated has been executed (Parameter 1).

The situation to be simulated for a particular 'run' is defined by eight parameters the first of which has already been mentioned. The second and third are the number of copies of the book available (Parameter 2) and the maximum number of reservations permitted at any one time (Parameter 3). The effect of having no restrictions on the number of reservations could, for practical purposes, be simulated by setting the maximum at some very high number. The remaining five will be introduced as needed while we discuss the details of the two primary events and their respective dependent events. The first primary event investigated by the model is the return of a copy of the book. If a copy has been returned it is replaced in stock and is again made available for loan. Before investigating the occurrence of the second primary event any outstanding reservations that we are now able to satisfy are satisfied. The reservation list and records of the delay pattern both being updated. The copy is taken out of stock again having been loaned to the person whose reservation request has just been satisfied.

The occurrence of the second primary event is now investigated. If a request for the book has been received the distribution for the inter-arrival time (i.e. the length of time between successive demands for the book) is immediately sampled to set up the time for the next request (Parameter 4). It is essential that we know the type of user making the request. Consequently the class of user distribution (Parameter 5) is sampled to determine his class. Two classes of user are catered for, borrowers and reference (i.e. in-library) users.

In the case of users who use the book in the library ('reference users'), it is assumed that, if a copy is available, then it will become unavailable until next morning. That is to

say that the user is allowed to use it for the remainder of the day. This is a conveniently simple assumption, but of course a program with a more sophisticated treatment of reference use could be devised if needed. If a copy is not available, then an additional unsatisfied reference request is recorded.

For borrowers the situation is much more complicated. If a copy of the book is available they are allowed to borrow it. The length of time that elapses before they return the book is found by sampling from the loan period distribution (Parameter 6). The book becomes unavailable for this duration of time unless it is recalled by a recall order. If no copy of the book is available we wish to know if a reservation request will be made so we sample from the reservation request distribution (Parameter 7). If no such request is made the borrower will be added to the count of unsatisfied borrowers. If a reservation request is made and the reservation list is not full the reservation is accepted and the borrower added to the bottom of the list. If the list is full the borrower is treated as being an unsatisfied borrower. Assuming a reservation request has been made and accepted, a recall order is now issued on the copy that has been out longest and is not already subject to a recall order. If there is a copy meeting these conditions then the recall distribution (Parameter 8) is sampled for the borrowers response to the recall notice and the return time for that copy is adjusted if necessary.

A complete cycle of the model has now been performed and the program will recycle to search for the time the next event is to occur, updating the simulated clocktime as it does so. The process is repeated until the simulation is complete.

The program allows for more than one situation to be simulated at any one run. Any or all of the parameters can be changed between the various situations considered. The time interval employed is a 'reference period' - assumed to be a quarter of a working day.

Results

At the end of each simulated situation, the program will output automatically the following information:

For reference users

(i) The total number of requests received from reference users;
(ii) Percentage of satisfied reference users.

For borrowers

(i) The total number of requests received from borrowers;
(ii) Percentage of satisfied borrowers;
(iii) Percentage of (i) satisfied immediately.
(iv) Histogram of delay experienced by borrowers having to reserve a copy of the book (includes the mean and standard deviation of the delay experienced).

Use

The program is contained as a binary dump on the magnetic tape PRØGRAMV LIBS and may be used inside the Lancaster University operating system by means of compiler binary. The data is on punched cards. The system cards required are:

```
TASKC/LAO1      name/
READ/PRØGRAMV   LIBS/
PRINT      m
SECØNDS    n
CØMPILER BINARY
20, MT, PRØGRAMV   LIBS
```

name is any document name the user cares to choose
m is the number of lines of print required (about 100 lines per situation to be simulated)
n is the running time for the simulation. This depends on the number of situations to be simulated and, for each situation, the number of requests to be simulated, the number of copies of the book kept and the number of reservations kept. A rough estimate would appear to be: 5+(3+x)y seconds per situation
x being the number of copies of the book stocked
y being the number of thousands of request to be simulated.

The document will contain the data as detailed below terminated with
****

Data

All data must be on punched cards. The program may be instructed to perform any of three functions by means of three heading cards:

PARAMETER
RUN
FINISH

The titles are punched in cols. 1-12 starting in col. 1. These will now be discussed individually.

PARAMETER

This indicates that the following card (or cards as the case may be) contains data on one of the eight program parameters. The parameter is identified by punching its number on the leading card anywhere on the card outside the title field (i.e. in cols. 13-80). A typical example would be:

PARAMETERVVV 7

The data needed for each of the eight parameters now follows. All data is punched in free format i.e. all fields must be separated by at least one space, otherwise they may be contained anywhere on the card.

Parameter 1

This is the number of requests to be simulated and is punched as a positive integer.

Parameter 2

This is the number of copies of the book and is punched as a positive integer.

Parameter 3

This is the maximum number of reservations kept at any one time and is punched as a positive integer.

Parameters 4-7 are all concerned with reading probability distributions which are input in this manner:

Card 1 contains two numbers, the first being the check sum of the probabilities and the second the total number of observations for the distribution. If there are, say, n observations, there will follow n further cards each containing two numbers. The two numbers are the probability associated with this observation and the value observed.

All numbers must be integers and there is a limit of 25 observations on each distribution (unless stated otherwise). The example in Note 1 will clarify this further.

Parameter 4

This is the distribution associated with the inter-arrival time; that is the time between successive demands for the book.

Parameter 5

This is the distribution associated with the class of user. There are only two possible observed values 1 and 2. Class 1 is a reference (i.e. in-library) user and class 2 a borrower. All that is required is that probabilities be associated with each class.

Parameter 6

This is the distribution associated with the loan period, i.e. the length of time the borrower has the book out of the library.

Parameter 7

This is the distribution associated with the reservation request, i.e. the probability that a reservation request will be made if no copy is available. There are only two observations permitted 0 and 1. 0 indicates yes, 1 indicates no. As with parameter 5 all that is needed is to associate a probability with each observation.

Parameter 8

This is the distribution associated with the response to a recall request. Three responses are permitted corresponding to immediate response, delayed response and total disregard. Probabilities must be associated with each response and the user must, of course, provide his own observed values for each response. Values of 12, 20 and 400 time intervals are suggested but the program will accept any observed values that the user may input.

To begin the simulation one or more situations in a single run, values for all eight parameters must be input or else the program cannot continue and will halt with the error message: 3.

For the second or subsequent situations in the same run only those parameters that are to be changed need be input. The previous values being assumed for any parameters that are not re-input. If a parameter number greater than 8 is defined the program will halt with the message: 2.

RUN

This initiates the simulation of the situation defined by the previous PARAMETER cards. Cols. 13-80 may contain a heading for the particular simulation and is printed out before the results for the simulation as an identifier. A RUN is needed for each situation to be simulated.

FINISH

This terminates the program which will be deleted with the message: 1.

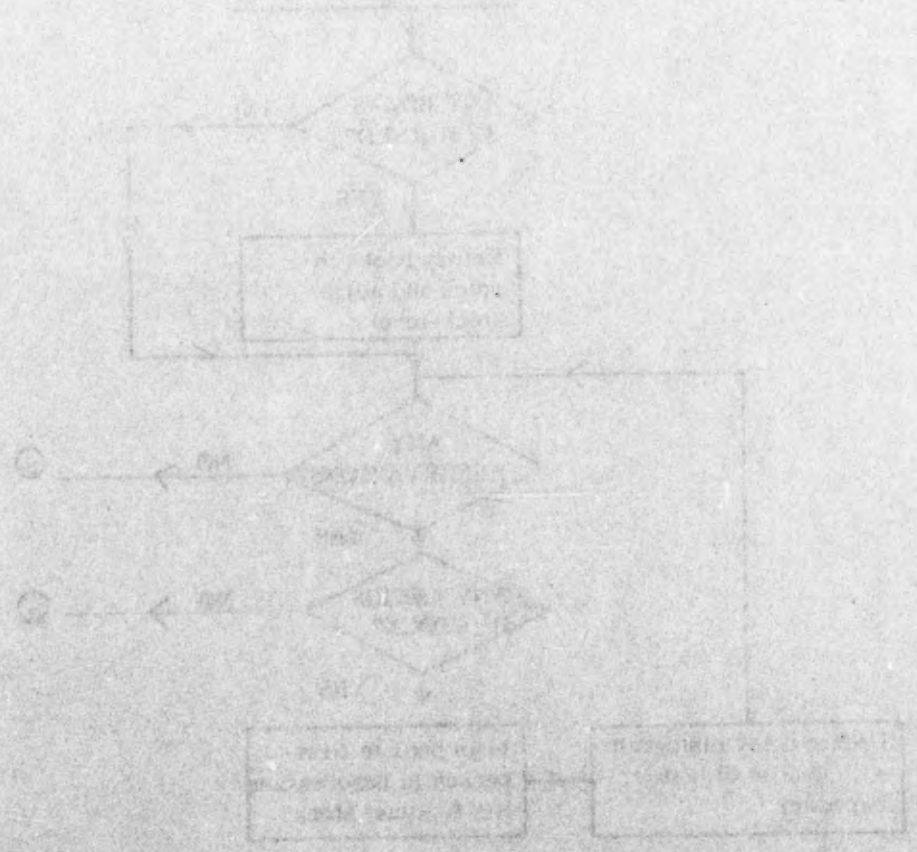
Note 1

A typical data set could be as follows:

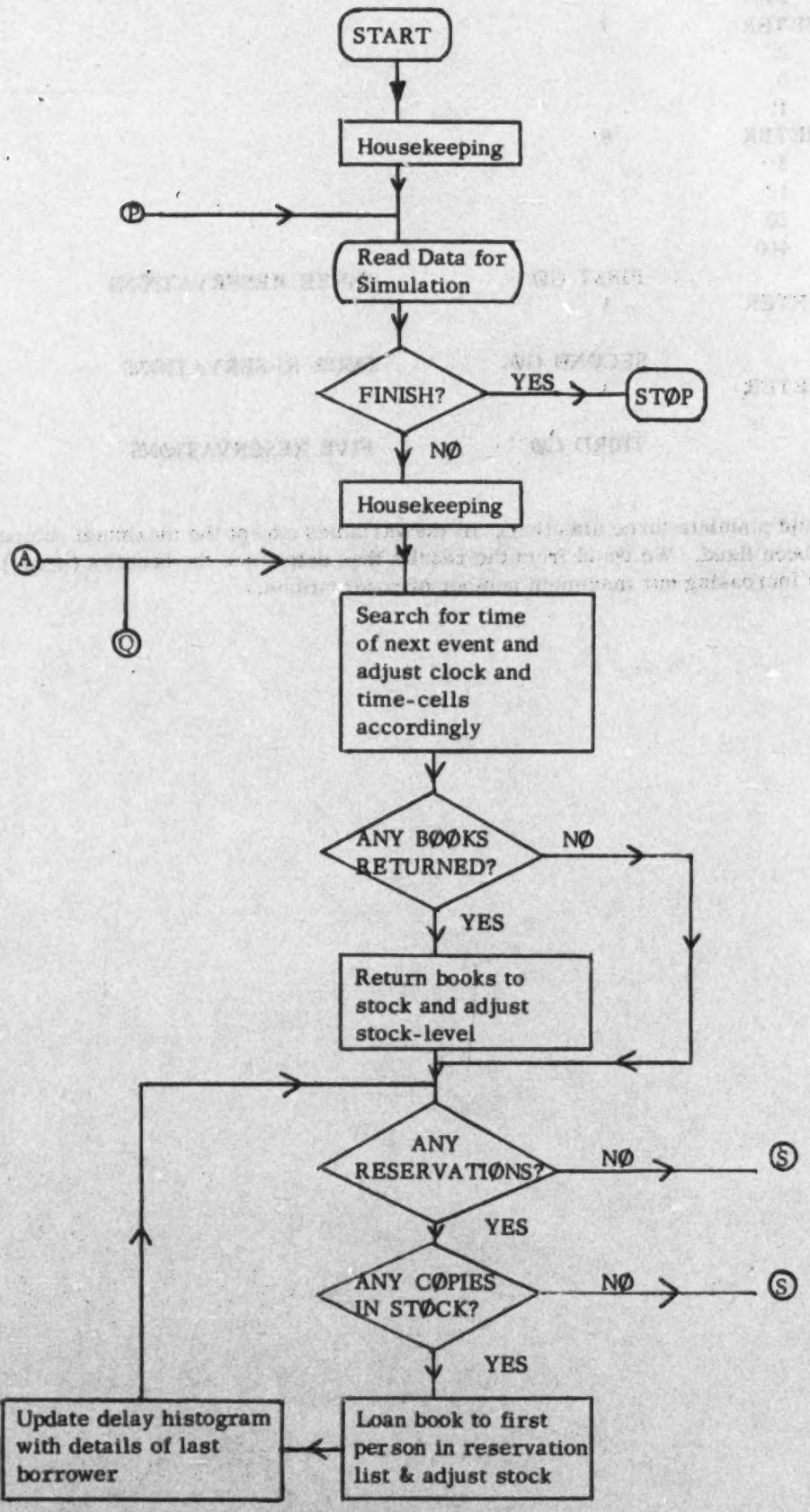
```
PARAMETER          1
5000
PARAMETER          2
3
PARAMETER          3
3
PARAMETER          4
100      3
33       20
33       40
34       60
PARAMETER          5
100      2
60       1
40       2
PARAMETER          6
100      5
50       20
```

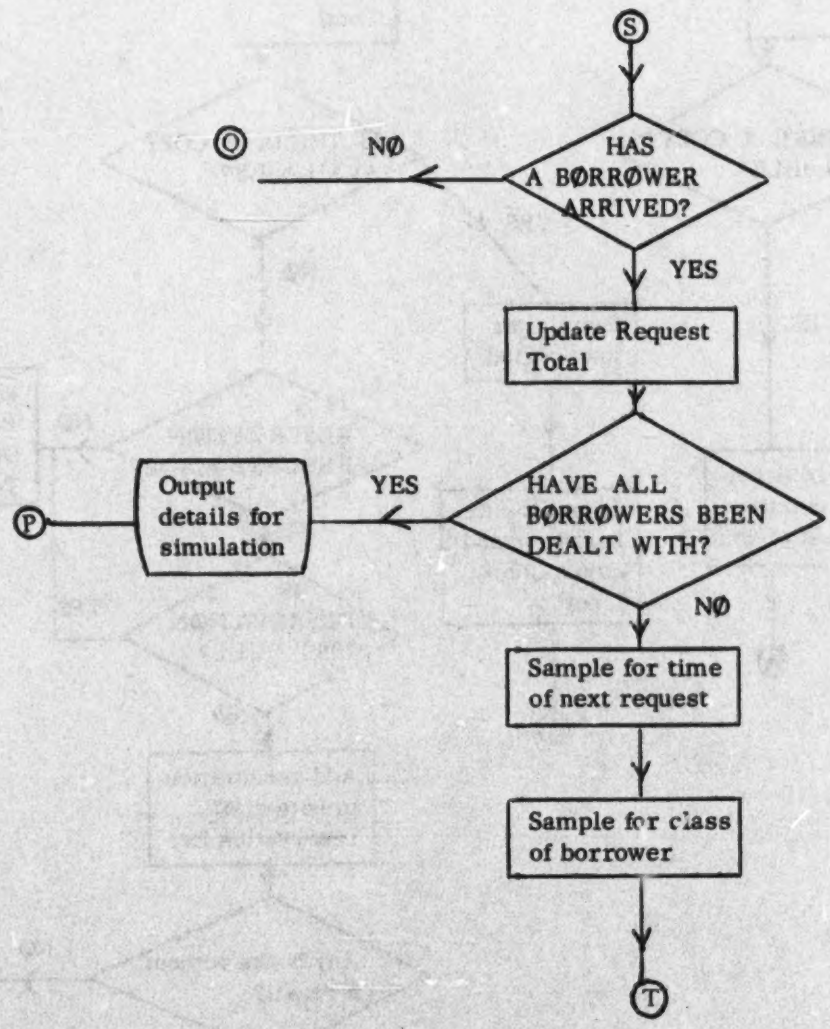
```
25        40
15        80
10        240
PARAMETER          7
100       2
50        0
50        1
PARAMETER          8
100       3
20        12
20        20
20        400
RUN                FIRST GØ       -     THREE RESERVATIØNS
PARAMETER          3
4
RUN                SECØND GØ      -     FØUR RESERVATIØNS
PARAMETER          3
5
RUN                THIRD GØ       -     FIVE RESERVATIØNS
FINISH.
```

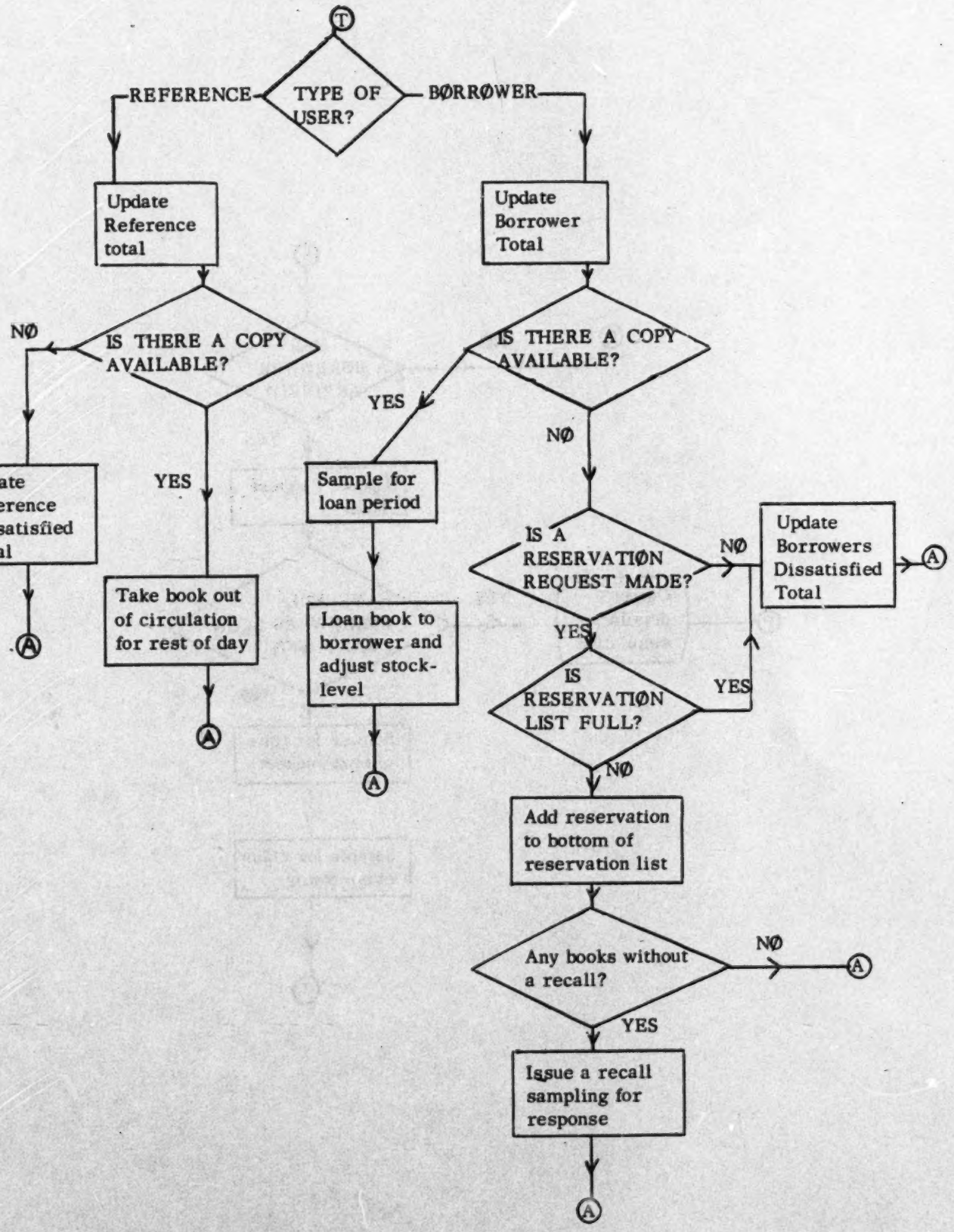
This would simulate three situations, all the variables except the maximum number of reservations been fixed. We could from the results thus determine the benefits (if any) to be made from increasing our maximum number of reservations.



Flow Diagram for LIBSIMO1




S
HAS A BØRRØWER ARRIVED?
NØ
O
YES
Update Request Total
HAVE ALL BØRRØWERS BEEN DEALT WITH?
YES
Output details for simulation
P
NØ
Sample for time of next request
Sample for class of borrower
T


T
TYPE OF USER?
REFERENCE
BØRRØWER
Update Reference total
Update Borrower Total
NØ
IS THERE A COPY AVAILABLE?
IS THERE A COPY AVAILABLE?
YES
NØ
Update Reference Dissatisfied Total
YES
Sample for loan period
IS A RESERVATIØN REQUEST MADE?
NØ
Update Borrowers Dissatisfied Total
A
Take book out of circulation for rest of day
Loan book to borrower and adjust stock-level
YES
IS RESERVATIØN LIST FULL?
YES
NØ
Add reservation to bottom of reservation list
Any books without a recall?
NØ
YES
Issue a recall sampling for response

LISTING OF LIBSIMO1

GENERAL LISTING (XQLP)

```
1          PROGRAM(LIBSIM01)                                                    LIB 0000
2          INPUT 1=CR0                                                          LIB 0001
3          OUTPUT 2=/ARRAY                                                      LIB 0004
4          OUTPUT 6=LP0                                                         LIB 0008
5          TRACE 0                                                              LIB 001A

6          COMPRESS INTEGER AND LOGICAL                                         LIB0020
7          END                                                                  LIB 0025
8          MASTER LIBRARY                                                       LIB 0030
9     C                                                                         LIB 0035
10    C THE VARIABLES USED IN THE SIMULATION ARE LISTED BELOW WITH BRIEF        LIB 0040

11    C DETAILS OF THEIR FUNCTIONS.                                             LIB 0045
12    C                                                                         LIB 0050
13    C   LOANPERIOD - A USER DEFINED DISTRIBUTION USED TO SAMPLE FOR THE       LIB 0055
14    C       LOAN PERIOD                                                       LIB 0060
15    C   REQUESTIME - A USER DEFINED DISTRIBUTION USED TO SAMPLE FOR THE       LIB 0065

16    C       TIME BETWEEN SUCCESSIVE REQUESTS                                  LIB 0070
17    C   RESERVATIONREQUEST - A USER DEFINED DISTRIBUTION USED TO DETERMINE    LIB 0075
18    C       THE LIKELYHOOD OF A RESERVATION REQUEST BEGIN MADE                LIB 0080
19    C   RECALLTIME - A USER DEFINED DISTRIBUTION USED TO SAMPLE FOR WHEN      LIB 0085
20    C       THE BOOK WILL BE RETURNED IF A RECALL REQUEST IS MADE             LIB 0090

21    C   CLASSOFUSER - PROBABILITY DISTRIBUTION ASSOCIATED WITH THE DIFFERINGLIB 0091
22    C                 CLASSES OF USER                                         LIB 0092
23    C   STOCK- AN ARRAY USED TO STORE INFORMATION CONCERNING THE VARIOUS      LIB 0095
24    C       COPIES OF THE BOOK. THE MAXIMUM NUMBER OF COPIES PERMITTED IS 50 LIB 0500
25    C       EACH ROW OF THE ARRAY RELATES TO ONE BOOK.                        LIB 0505

26    C         COLUMN 1 RECORDS THE DATE THE BOOK WILL RETURN                  LIB 0510
27    C         COLUMN 2 RECORDS THE DATE THE BOOK WAS TAKEN OUT                LIB 0515
28    C         COLUMN 3 INDICATES IF A RECALL HAS BEEN MADE ON THE BOOK        LIB 0520
29    C   CLASS - CURRENT USER TYPE                                             LIB 0521
30    C               1 IF REFERENCE USER                                       LIB 0522

31    C               2 IF BORROWER                                             LIB 0523
32    C   RESERVED - A VECTOR TO RECORD THE DATES RESERVATIONS WERE MADE. THE   LIB 0525
33    C   RUN - 1 IF FIRST SIMULATION                                           LIB 0526
34    C         2 IF OTHER THAN FIRST SIMULATION                                LIB 0527
35    C       MAXIMUM NUMBER OF RESERVATIONS THAT CAN BE ACCOMODATED IS 50      LIB 0530

36    C   INSTOCK - THE NUMBER OF BOOKS AVAILABLE TO BE LOANED AT ANY TIME      LIB 0535
37    C   FIRSTRESERVE -INDICATES POSITION IN THE VECTOR RESERVED OF THE        LIB 0540
38    C       FIRST RESERVATION TO BE SATISFIED                                 LIB 0545
39    C   RESERVATIONS - THE NUMBER OF RESERVATIONS OUTSTANDING AT ANY INSTANT  LIB 0550
40    C   NEXTRESERVE - POSITION IN RESERVED TO STORE DETAILS OF THE NEXT       LIB 0555

41    C       RESERVATION MADE                                                  LIB 0560
42    C   MAXBOOKS -THE NUMBER OF COPIES OF THE BOOK AVAILABLE FOR LOANING      LIB 0565
43    C  MAXRESERVES -    THE MAXIMUN NUBER OF RESERVATIONS PERMITTED AT ANY    LIB 0570
44    C       ONE TIME                                                          LIB 0575
45    C   BORROWER - COUNT OF NUMBER OF BORROWERS                               LIB 057A

46    C   RESERVER - COUNT OF NUMBER OF RESERVATIONS                            LIB 0577
47    C   REFERENCE - COUNT OF NUMBER OF REFERENCE USERS                        LIB 057B
48    C   CLOCK - CURRENT SIMULATION TIME                                       LIB 0580
49    C   LEASTIME - TIME NEXT EVENT OCCURS                                     LIB 0585
50    C   NEXTREQUEST - TIME NEXT REQUEST FOR A LOAN WILL BE MADE               LIB 0590

51    C   DELAY - IS A HISTOGRAM WITH 12 CELLS FOR RECORDING HISTORICAL         LIB 0595
52    C       INFORMATION ON THE WAITING PERIOD FOR RESERVED BOOKS              LIB 1000
53    C   DISATISFIEDR- NUMBER OF REQUESTS NOT SATISFIED (LOAN)                 LIB 1005
54    C   DISATISFIEDR- NUMBER OF REQUESTS NOT SATISFIED (REFERENCE)            LIB 1006
55    C   TERMINATE - NUMBER OF REQUESTS TO BE SIMULATED                        LIB 1010

56    C   I,J,HEADING,Y ARE WORK AREAS                                          LIB 1015
57    C   BOOKSREQUEST - TALLY OF REQUESTS MADE                                 LIB 1020
58    C   LIST - A VECTOR TO STORE DETAILS FOR THE RANDOM NUMBER GENERATOR      LIB 1021
59    C   COUNT - KEEPS TRACK OF THE PARAMETERS THAT HAVE BEEN INPUT            LIB 1022
60    C  SWITCH - NORMALLY SET TO 1 IF SET TO 2 RECYCLE IS REQUIRED I.E.        LIB 1023

61    C                       FURTHER SCAN OF EVENTS WITHOUT TIME ADVANCE        LIB 1024
62    C                                                                         LIB 1025
63    C                                                                         LIB 1030
64    C                                                                         LIB 1035
65    C DEFINE VARIABLES REQUIRED                                               LIB 1040

66    C                                                                         LIB 1045
67          INTEGER STOCK(50,3),RESERVED(50)                                    LIB 1050
68          INTEGER DELAY(22),HEADING(20)                                       LIB 1055
69          INTEGER LOANPERIOD(24,2),REQUESTIME(26,2),RESERVATIONREQUEST(4,2),LIB 1060
70         1        RECALLTIME(24,2),CLASSOFUSER(3,2)                         LIB 1065
71          INTEGER FIRSTRESERVE,NEXTRESERVE,RESERVATIONS,INSTOCK               LIB 1070
72          INTEGER MAXBOOKS,MAXRESERVES                                        LIB 1075
73          INTEGER LEASTIME,NEXTREQUEST,CLOCK                                  LIB 1080
74          INTEGER RUN,COUNT                                                   LIB 1082
75          INTEGER SAMPLE,LIST(5),TERMINATE,BOOKSREQUESTED                     LIB 1083

76          INTEGER DISATISFIEDB,DISATISFIEDR,BORROWER,RESERVED,REFERENCE       LIB 1084
77          INTEGER SWITCH,CLASS                                                LIB 1085
78          DATATEST/INDEF/                                                     LIB 1086
79          LIST(1),LIST(2),LIST(3),LIST(4),LIST(5)=125                         LIB 1087
80          RUN=1                                                               LIB 1088
```

```
      COUNT=0                                                          LIB 1490
      CALL DEFBUF(2,80,HEADING)                                        LIB 1500
C                                                                      LIB 1501
C READ IN DATA                                                         LIB 1505
C                                                                      LIB 1496

  500 READ(1,700)HEADING                                               LIB 1500
      IF(ITEXTCOMP(1,HEADING(1),1,TEST,1))0,501,0                      LIB 1501
      IF(ITEXTCOMP(1,HEADING(1),1,TEST,2))0,502,0                      LIB 1502
      IF(ITEXTCOMP(1,HEADING(1),1,TEST,3).EQ.0)STOP 1                  LIB 1503
      GOTO 500                                                         LIB 1504

C  PARAMETER                                                           LIB 1505
  501 READ(2,701) I                                                    LIB 1506
      IF(I.LT.1.OR.I.GT.8) STOP 2                                      LIB 1507
      GO=+.+V+1.02/+.GT.(K4,V09,716,517,518),I                         LIB 1508
C     NUMBER OF REQUESTS TO BE SIMULATED                               LIB 1509

  511 READ(1,702)TERMINATE                                             LIB 1510
      COUNT=COUNT+1                                                    LIB 1511
      GOTO 500                                                         LIB 1512
C      READ NUMBER OF COPIES OF BOOK STOCKED                           LIB 1513
  512 READ(1,702)MAXBOOKS                                              LIB 1514

      COUNT=COUNT+2                                                    LIB 1515
      GOTO 500                                                         LIB 1516
C     MAXIMUM NUMBER OF RESERVATIONS KEPT                              LIB 1517
  513 READ(1,702)MAXRESERVS                                            LIB 1518
      COUNT=COUNT+3                                                    LIB 1519

      GOTO 500                                                         LIB 1520
C     REQUEST RATE DISTRIBUTION                                        LIB 1521
  514 READ(1,702) REQUESTIME(1,1),REQUESTIME(1,2)                      LIB 1522
      READ(1,702)(REQUESTIME(I,1),REQUESTIME(I,2),I=2,REQUESTIME(1,2)+1)LIB 1523
      CALL DISTRIBUTE(REQUESTIME)                                      LIB 1524

      COUNT=COUNT+4                                                    LIB 1525
      GOTO 500                                                         LIB 1526
C     RESERVATION REQUEST LIKELYHOOD                                   LIB 1527
  515 READ(1,702)CLASSOFUSER(1,1),CLASSOFUSER(1,2)                     LIB 1528
      READ(1,702)(CLASSOFUSER(I,1),CLASSOFUSER(I,2),I=2,CLASSOFUSER(1,2)LIB 1529

     1+1)                                                              LIB 1530
      CALL DISTRIBUTE(CLASSOFUSER)                                     LIB 1531
      COUNT=COUNT+5                                                    LIB 1532
      GOTO 500                                                         LIB 1533
C     LOAN PERIOD DISTRIBUTION                                         LIB 1534

  516 READ(1,702) LOANPERIOD(1,1),LOANPERIOD(1,2)                      LIB 1535
      READ(1,702)(LOANPERIOD(I,1),LOANPERIOD(I,2),I=2,LOANPERIOD(1,2)+1)LIB 1536
      CALL  DISTRIBUTE(LOANPERIOD)                                     LIB 1537
      COUNT=COUNT+6                                                    LIB 1538
      GOTO 500                                                         LIB 1539

  517 READ(1,702) RESERVATIONREQUEST(1,1),RESERVATIONREQUEST(1,2)      LIB 1540
      READ(1,702) (RESERVATIONREQUEST(I,1),RESERVATIONREQUEST(I,2),I=2,3LIB 1541
     1)                                                                LIB 1542
      CALL DISTRIBUTE(RESERVATIONREQUEST)                              LIB 1543
      COUNT=COUNT+7                                                    LIB 1544

      GOTO 500                                                         LIB 1545
  518 READ(1,702) RECALLTIME(1,1),RECALLTIME(1,2)                      LIB 1547
      READ(1,702)(RECALLTIME(I,1),RECALLTIME(I,2),I=2,RECALLTIME(1,2)+1)LIB 1548
      CALL  DISTRIBUTE(RECALLTIME)                                     LIB 1549
      COUNT=COUNT+8                                                    LIB 1550

      GOTO 500                                                         LIB 1551
C  RUN PROGRAM                                                         LIB 1470
  502 IF(RUN.EQ.1) GOTO 522                                            LIB 1571
      RUN=2                                                            LIB 1572
      IF(COUNT.NE.36) STOP 3                                           LIB 1573

C     RECALL DISTRIBUTION                                              LIB 1546
  522 WRITE(6,704)(HEADING(I),I=4,20)                                  LIB 1574
C                                                                      LIB 1575
C CARRY OUT INITIALIRATION ROUTINES                                    LIB 1500
C                                                                      LIB 1505
      RESERVER=0                                                       LIB 1506
      SWITCH=1                                                         LIB 1507
      DISATISFIED=0                                                    LIB 1508
      DISATISFIED=0                                                    LIB 1509
      REFERENCE=0                                                      LIB 1600

      BORROWER=0                                                       LIB 1601
      CLOCK=0                                                          LIB 2000
      NEXTREQUEST=0                                                    LIB 2005
      INSTOCK=MAXBOOKS                                                 LIB 2006
      NEXTRESERVE=1                                                    LIB 2007

      BOOKSREQUESTED=0                                                 LIB 2008
      FIRSTRESERVE=1                                                   LIB 2009
      RESERVATIONS=0                                                   LIB 2010
      DO 100 I=1,MAXBOOKS                                              LIB 2015
  100 STOCK(I,1)=-1

      CALL DEFINNISY(DELAY,4.0,4.0)                                    LIB 2016
      CALL INITRANDOM(5,LIST)                                          LIB 2017
C                                                                      LIB 2025
C                                                                      LIB 2030
C START SIMULATION                                                     LIB 2035
```

```
C                                                                       LIB 2070
C                                                                       LIB 2065
C TIME ADVANCE                                                          LIB 2060
C                                                                       LIB 2055
C                                                                       LIB 2050

 1000 GOTO (1004,1003),SWITCH                                           LIB 2045
 1004 LEASTIME=NEXTREQUEST                                              LIB 2042
      DO 1001 I=1,MAXBOOKS                                              LIB 2070
      IF(STOCK(I,1).LE.0) GOTO 1001                                     LIB 2075
      IF(STOCK(I,1).LT.LEASTIME) LEASTIME=STOCK(I,1)                    LIB 2080

 1001 CONTINUE                                                          LIB 2085
      CLOCK=CLOCK+LEASTIME                                              LIB 2090
      NEXTREQUEST=NEXTREQUEST-LEASTIME                                  LIB 2095
      DO 1002 I=1,MAXBOOKS                                              LIB 2500
 1002 STOCK(I,1)=STOCK(I,1)-LEASTIME                                    LIB 2505

C                                                                       LIB 2510
C                                                                       LIB 2515
C ACCEPT RETURNED BOOKS                                                 LIB 2520
C                                                                       LIB 2525
C                                                                       LIB 2530

 1003 SWITCH=1                                                          LIB 2531
      DO 2000 I=1,MAXBOOKS                                              LIB 2535
      IF(STOCK(I,1).NE.0) GOTO 2000                                     LIB 2540
      STOCK(I,3)=0                                                      LIB 2545
      INSTOCK=INSTOCK+1                                                 LIB 2550

 2000 CONTINUE                                                          LIB 2555
C                                                                       LIB 2560
C                                                                       LIB 2565
C SATISFY ANY OUTSTANDING RESERVATIONS                                  LIB 2570
C                                                                       LIB 2575

C                                                                       LIB 2580
      DO 3000 I=1,MAXBOOKS                                              LIB 2585
      IF(RESERVATIONS.EQ.0) GOTO 4000                                   LIB 2590
      IF(INSTOCK.EQ.0) GOTO 4000                                        LIB 2595
      IF(STOCK(I,1).GT.0) GOTO 3000                                     LIB 3000

      Z=CLOCK-RESERVED(FIRSTRESERVE)                                    LIB 3005
      CALL ADDTOHIST(Z,DELAY)                                           LIB 3010
      RESERVATIONS=RESERVATIONS-1                                       LIB 3015
      FIRSTRESERVE=FIRSTRESERVE+1                                       LIB 3020
      IF(FIRSTRESERVE.GT.MAXRESERVES) FIRSTRESERVE=1                    LIB 3025

      INSTOCK=INSTOCK-1                                                 LIB 3030
      STOCK(I,1)=SAMPLE(1,LOANPERIOD)                                   LIB 3035
      STOCK(I,2)=CLOCK                                                  LIB 3040
 3000 CONTINUE                                                          LIB 3045
C                                                                       LIB 3050

C                                                                       LIB 3055
C ACCEPT REQUESTS                                                       LIB 3060
C                                                                       LIB 3065
C                                                                       LIB 3070
 4000 IF(NEXTREQUEST.NE.0) GOTO 1000                                    LIB 3075
      BOOKS REQUESTED=BOOKSREQUESTED+1                                  LIB 3080
      IF(BOOKSREQUESTED.GT.TERMINATE) GOTO 999                          LIB 3085
      NEXTREQUEST=SAMPLE(2,REQUESTIME)                                  LIB 3090
      IF(NEXTREQUEST.EQ.0) SWITCH=2                                     LIB 3091
C                                                                       LIB 3092

C                                                                       LIB 3093
C  SAMPLE FOR CLASS OF USER                                             LIB 3094
C                                                                       LIB 3095
C                                                                       LIB 3096
      CLASS=SAMPLE(3,CLASSOFUSER)                                       LIB 3097

      IF(CLASS.EQ.2) GOTO 5001                                          LIB 3098
C                                                                       LIB 3099
C                                                                       LIB 3100
C  REFERENCE USER                                                       LIB 3101
C                                                                       LIB 3102

C                                                                       LIB 3103
      REFERENCE=REFERENCE+1                                             LIB 3104
      IF(INSTOCK.EQ.0) GOTO 4500                                        LIB 3106
      DO 4501 I=1,MAXBOOKS                                              LIB 3107
      IF(STOCK(I,1).GT.0) GOTO 4501                                     LIB 3108

      STOCK(I,1)=4+NOD(CLOCK,4)                                         LIB 3109
      INSTOCK=INSTOCK-1                                                 LIB 3110
      STOCK(I,2)=CLOCK                                                  LIB 3111
      GOTO 1000                                                         LIB 3112
 4501 CONTINUE                                                          LIB 3113

      STOP 99                                                           LIB 3114
 4500 DISATISFIED=DISATISFIED+1                                         LIB 3116
      GOTO 1000                                                         LIB 3117
C                                                                       LIB 3500
C                                                                       LIB 3505

C  BORROWER                                                             LIB 3510
C                                                                       LIB 3515
C                                                                       LIB 3520
 5001 BORROWER=BORROWER+1                                               LIB 3525
      IF(INSTOCK.EQ.0) GOTO 4000                                        LIB 3095
```

```
291           DO 5000 I=1,MAXBOOKS                                      LIB 3525
292           IF(STOCK(I,1).GT.0) GOTO 5000                             LIB 3530
293           STOCK(I,1)=SAMPLE(1,LOANPERIOD)                           LIB 3535
294           INSTOCK=INSTOCK+1                                         LIB 3540
295           STOCK(I,2)=CLOCK                                          LIB 3545

296           GOTO 1000                                                 LIB 3550
297      5000 CONTINUE                                                  LIB 3555
298           STOP 90                                                   LIB 3560
299      C                                                              LIB 3565
300      C                                                              LIB 3570

301      C RESERVATION REQUEST                                          LIB 3575
302      C                                                              LIB 3580
303      C                                                              LIB 3585
304      6000 IF(SAMPLE(3,RESERVATIONREQUEST).EQ.0) GOTO 7000           LIB 3590
305      C                                                              LIB 3595

306      C                                                              LIB 4000
307      C NO RESERVATION REQUEST MADE -REQUEST NOT SATISFIED           LIB 4005
308      C                                                              LIB 4010
309      C                                                              LIB 4015
310      6001 DISATISFIEDB=DISATISFIEDB+1                               LIB 4020

311           GOTO 1000                                                 LIB 4025
312      C                                                              LIB 4030
313      C                                                              LIB 4035
314      C RESERVATION ATTEMPT                                          LIB 4040
315      C                                                              LIB 4045
316      C                                                              LIB 4050
317      7000 IF(RESERVATIONS.EQ.MAXRESERVES) GOTO 6001                 LIB 4055
318           RESERVER=RESERVER+1                                       LIB 4056
319           RESERVATIONS=RESERVATIONS+1                               LIB 4057
320           RESERVED(NEXTRESERVE)=CLOCK                               LIB 4060

321           NEXTRESERVE=NEXTRESERVE+1                                 LIB 4065
322           IF(NEXTRESERVE.GT.MAXRESERVES)NEXTRESERVE=1               LIB 4070
323      C                                                              LIB 4075
324      C                                                              LIB 4080
325      C ISSUE RECALL ORDER IF POSSIBLE                               LIB 4085

326      C                                                              LIB 4090
327      C                                                              LIB 4095
328           I=SAMPLE(4,RECALLTIME)                                    LIB 4500
329           DO 8000 J=1,MAXBOOKS                                      LIB 4505
330           IF(STOCK(J,3).EQ.0.AND.STOCK(J,1).GT.I) GOTO 8001         LIB 4510

331      8000 CONTINUE                                                  LIB 4520
332           GOTO 1000                                                 LIB 4525
333      8001 STOCK(J,1)=I                                              LIB 4530
334           STOCK(J,3)=1                                              LIB 4535
335           GOTO 1000                                                 LIB 4540

336      C                                                              LIB 4545
337      C                                                              LIB 4550
338      C CLOSE ROUTINES                                               LIB 4555
339      C                                                              LIB 4560
340        999 WRITE(6,707)                                             LIB 4561

341           WRITE(6,711)                                              LIB 4562
342           Z=FLOAT(REFERENCE-DISATISFIEDR)/REFERENCE*100.            LIB 4563
343           WRITE(6,708) Z                                            LIB 4564
344           WRITE(6,709)                                              LIB 4565
345           WRITE(6,710)                                              LIB 4566

346           Z=FLOAT(BORROWER-DISATISFIEDB)/BORROWER*100.              LIB 4567
347           WRITE(6,712) Z                                            LIB 4568
348           Z=FLOAT(BORROWER-DISATISFIEDB-RESERVER)/BORROWER*100.     LIB 4569
349           WRITE(6,713) Z                                            LIB 4570
350           CALL SCATHIST(DELAY)                                      LIB 4571

351           GOTO 500                                                  LIB 4572
352        700 FORMAT(20A4)                                             LIB 4575
353        701 FORMAT(12X,I0)                                           LIB 4580
354        702 FORMAT(2000I0)                                           LIB 4585
355        703 FORMAT(30HONUMBER OF COPIES IN STOCK IS ,I2/              LIB 4590

356           144HOTHE MAXIMUM NUMBER OF RESERVATIONS KEPT IS ,I2/      LIB 4595
357           243HOTHE NUMBER OF REQUESTS TO BE SIMULATED IS ,I5)       LIB 4600
358        704 FORMAT(84HOTHE HISTORICAL DATA DETAILED ABOVE RELATES TO THE WAITILIB 4605
359           1NG PERIOD FOR-RESERVED BOOKS)                            LIB 4610
360        706 FORMAT(1H1,24X,17A4)                                     LIB 4615

361        707 FORMAT(///16H REFERENCE USERS)                           LIB 4617
362        708 FORMAT(49HOTHE PERCENTAGE OF SATISFIED REFERENCE USERS WAS ,F6.2) LIB 4618
363        709 FORMAT(///10H BORROWERS)                                 LIB 4619
364        710 FORMAT(10H ----------///)                                LIB 4620
365        711 FORMAT(16H ---------- -----///)                          LIB 4621

366        712 FORMAT(43HOTHE PERCENTAGE OF SATISFIED BORROWERS WAS ,F5.2) LIB 4642
367        713 FORMAT(60HOTHE PERCENTAGE OF SATISFIED BORROWERS AT FIRST REQUEST LIB 4643
368           1WAS ,F5.2)                                               LIB 4644
369             END                                                     LIB 4645
370             LIBRARY                                                 LIB 4672

371             READ FROM(MT,OR FORTRAN.HIST)                           LIB 4645
372             READ FROM (MT,,CHARACTER)                               LIB 4646
373             READ FROM (MT,,RANDOMA)                                 LIB 4647
374             FINISH                                                  LIB 4650
          ****++FINISH
```

```
OPERATING SYSTEM MESSAGE -  ALLOK WELL THAT ENDS WELL
RA15LIST7
C  78.T    0.P  404,MT  0
CON    5,CON  0.EX     0,TOT   25,P= 3.5=10406
COST=£  1.85
****
```

APPENDIX B: DATA COLLECTION

B.1. OTHER THAN THE UNIVERSITY OF LANCASTER

Origins

Enquiries were made concerning the loan regulations and issue systems of most British university libraries. Manchester, Strathclyde and Sussex were asked to help because the discharged issue slips of these libraries were convenient to handle and represented a suitable range of loan periods and subject interests. It had been hoped to collect data from a wider range of libraries and to analyse them more intensively but resources were inadequate for the purpose. Within the limits of the data, the findings are clear and consistent.

Daily bundles of discharged slips were collected as follows:

Manchester: All discharged slips from the Main Library, 10-15 March 1969.

Strathclyde: All discharged slips from the Andersonian Library, 3-15 February 1969.

Sussex: All discharged fortnightly loans by undergraduates from the main library, 14-27 February 1969.

Analysis

The slips were analysed as follows:

i. Procedures ii-x below were conducted quite separately for each of the daily bundles of discharged slips.

ii. Each slip was stamped with the date of return as a precautionary measure.

iii. Each daily bundle was sorted into categories according to the official loan period and whether or not there had been a reservation. For example for Strathclyde there were four categories:

4 weeks (Staff & Postgraduates): No reservation
4 weeks (Staff & Postgraduates): Reservation
2 weeks (Undergraduates): No reservation
2 weeks (Undergraduates): Reservation

iv. Procedures v-viii below were conducted quite separately for each category.

v. Each category was then sorted by the number of times (if any) that the loan had been renewed and the number of loans renewed 0, 1, 2, 3... times was counted. A summary of results may be found in Table B2 on page

vi. Slips representing loans which were not renewed were sorted by date of borrowing. The distribution of lengths of loan was calculated by counting the number of slips relating to each date of borrowing and by comparing the date of borrowing with the date of return. An item borrowed and then returned on the same day was regarded as having been retained for 0 days. An item borrowed one day and returned the next day was regarded as having been kept out for 1 day, and so on.

vii. Slips relating to loans which had been renewed one or more times were sorted by date of original borrowing in order to establish the distribution of lengths of loan between original borrowing and final return. The procedure was the same as vi above.

viii. Slips relating to loans which had been renewed one or more times were re-sorted by date of final renewal in order to establish the distribution of the lengths of time between the final renewal and final return. The procedure was the same as in vi above.

ix. The frequency of renewal (derived in v. above) for each daily bundle of discharged slips was summed within each category.

x. The frequency of length of loan (derived from vi-viii above) for each daily bundle of discharged slips was summed within each category.

All analyses were manual except in the case of Sussex two-week loans for which the slips are in the form of 80 column Hollerith cards and are already partially punched. For these, procedures vi and viii were performed by computer and procedure vii was not possible.

Where a particular part of a slip was not clear it was excluded from analyses involving that particular part, but included for other analyses for which the relevant parts were clear. For this reason some of the totals do not always tally as one would expect. For example the totals in categories B and C should be the same. No attempt was made to verify the punching of the Sussex data. Very few appear to have been mispunched, but 59 items (which were apparently long overdue (almost all 9-10 months) were treated as mispunched and excluded.

In the case of Strathclyde a further analysis was made of the borrowing of science literature as defined by UDC classes 5 and 6. Note that this data excludes periodicals, which are subject to a one week loan period.

A summary of the data is presented in Table B1 on pages B.4-B.8.

Data relating to the University of Michigan is presented by Burkhalter (33) and we are grateful to the University of Strathclyde for permission to examine data collected there in earlier years.

B.2. LANCASTER DATA

Lancaster data related to a fixed date of return: the end of term for undergraduates and the end of the session for teaching staff. Therefore the official loan period varies from day to day in contrast with a fixed loan period, such as a week, which remains constant whenever the item was borrowed. In principle one could pick a single day at a specified length of time before books were due back and analyse what happened to books borrowed on that day. Unfortunately too few items were borrowed on each day to permit a meaningful analysis. Some exploratory analyses were attempted on a random sample of returns in which the time kept out was expressed not in days but as a fraction of the time allowed out.

The histogram presented in chapter 6, Figure 6.4 on page 45, was derived as follows. The precise date on which books were due back was identified and the period of one week was identified which was 50-56 days before the date on which books were due back. A separate analysis was then made of the books borrowed on each of these days. The length of time that books were kept out was analysed into the following groups:

0 - 7 days	36-42 days
8 - 14 days	43-49 days
15 - 21 days	50-56 days
22 - 28 days	over 56 days
29 - 35 days	

The results for each day were then summed group by group and converted to a percentage of the total borrowings of that week. For all days, the date due back fell within the group 50-56 days and this is reflected in the histogram.

TABLE B1: Summary of data on length of borrowing

Key: No reservation:
Not renewed:
A: Time between borrowing and return.
Renewed:
B: Time between original borrowing and final return.
C: Time between latest renewal and final return.
Reservation:
Not renewed:
E: Time between borrowing and return.
Renewed:
F: Time between original borrowing and final return.
G: Time between latest renewal and final return.

Brackets denote science literature as defined by UDC classes 5 and 6.

OFFICIAL LOAN PERIOD:	7 DAYS						14 DAYS													
SOURCE:	MANCHESTER: Undergraduates						STRATHCLYDE: Undergraduates								SUSSEX: Undergraduates					
	A	B	C	E	F	G	A	(A)	B	(B)	C	(C)	E	(E)	F	(F)	G	(G)	A	C	E	G
DAYS																						DAYS
0	1		14				13	(3)			1	(1)	1	(1)					0	0		0
1	106		17				48	(17)			14	(3)	1						306	2		1
2	58		12	3		2	35	(13)			2		3	(1)					274	1		2
3	82		27	3		1	66	(20)			9	(2)	1						306	3		3
4	91		36	1		1	35	(15)			6								366	7		4
5	109		40	3			30	(10)			5	(2)	1						227	4		5
6	160	2	64	3		3	55	(19)			7	(1)	1				1	(1)	246	2	1	6
7	445	6	337	30		11	76	(26)			17	(2)	2						410	15		7
8	102	11	46	14		13	41	(17)	1		6	(1)							270	8		8
9	39	14	13	7	1	4	40	(12)			6	(3)	2	(1)					176	8	1	9
10	36	12	29	6	1	1	43	(25)			4	(2)	1				1		219	8	1	10
11	38	12	14	7		3	68	(23)			14	(7)	3	(1)			1		305	15		11
12	25	17	7	3	1	2	83	(26)	1		12	(4)	6	(3)			1		236	7	1	12
13	4	54	10	5	1	2	142	(56)			24	(12)	15	(5)					458	30	8	13
14	16	169	6		7		421	(198)	2	(1)	146	(84)	35	(15)			9	(6)	1343	115	4	14
15	11	34	1	1	5	1	91	(44)	3		21	(8)	27	(13)			4		558	39	9	1 15
16	7	15			2	1	39	(25)	1		15	(8)	4	(1)			1		210	12	5	1 16
17	3	33	3				60	(22)	8	(3)	10	(6)	5	(4)			2	(1)	169	13	5	1 17
18	15	15	4		3		47	(12)	3		9	(5)	6	(2)					137	16	3	18
19	5	18		1			44	(18)	4	(1)	14	(9)	5	(2)	1	(1)			100	6	3	19
20	3	17			2		49	(16)	3		7	(4)	10	(5)			2	(1)	62	3		20
21	6	49	1		5	1	55	(17)	12	(3)	14	(10)	6	(1)			2		120	6	1	21

OFFICIAL LOAN PERIOD:	7 DAYS						14 DAYS														
SOURCE:	MANCHESTER: Undergraduates						STRATHCLYDE: Undergraduates										SUSSEX: Undergraduates				
	A	B	C	E	F	G	A	(A)	B	(B)	C	(C)	E	(E)	F	(F)	G	(G)	A	C	E	G
DAYS																						DAYS
22	4	17	3		3		29	(14)	5	(1)	6	(1)	4	(4)			4	(1)	63			22
23	0	3	1		2		14	(8)			2		1						25		1	23
24	2	7			1		7	(5)	8	(4)	1								44	2	1	24
25	2	8			2		8	(4)	8	(5)			2	(2)	1				30			25
26	1	9			1		7	(5)	9	(4)	2	(2)	1				2	(2)	30			26
27	1	17	2				8	(3)	31	(13)	3	(3)	3	(1)					21	1		27
28	2	22		1	1		12	(5)	63	(32)	9	(8)	1		8	(5)			26			28
29	2	9			1		1		19	(8)			2	(1)	1				13		1	29
30	1	3			1		3	(2)	15	(9)					1				1			30
31	1	5			2		1	(1)	12	(5)	1		1	(1)					8		1	31
32		7	1				1		8	(2)	1				1				21		1	32
33	1	7	1				2		4	(1)									4			33
34	4	8		1	1		1		6	(2)									2			34
35	4	14		1	1		2	(2)	6	(2)	1	(1)							10			35
36		9		1			2	(1)	3	(1)			1	(1)					1			36
37		5					1		5	(1)	1											37
38		3				1			3						1				2			38
39		5					1		3	(1)					1	(1)						39
40		1							2	(2)									2			40
41		2	1						2	(1)	2	(2)										41
42	2	4							9	(7)	1				1				1			42
43	1	3	1						2	(2)					1	(1)			6			43
44		3							1										4			44
45		1					2	(2)	1	(1)									4			45
46	1	1							1										6			46
47		3																				47
48		5																				48
49		6					1		2	(1)			1	(1)					1			49
50		4		1	1				3	(1)									5			50
51		2																	2			51
52		1							9	(3)									1		1	52
53		4							4	(1)												53
54	1	2							1	(1)					1							54
55									5	(4)												55
56					1				11	(8)					1							56
57- 63		2			1		3	(2)	21	(13)					4	(2)						57-63
64- 70		1					1		13	(5)	1	(1)			1	(1)						64-70
71- 77							1		19	(13)					1							71-77
78- 84	1						1		13	(11)												78-84
85- 91	9	5					1	(1)	8	(6)			1		2							85-91

OFFICIAL LOAN PERIOD: 7 DAYS

SOURCE: MANCHESTER Undergraduates

DAYS	A	B	C	E	F	G
92- 98		4				
99-105						
106-112						
113-119						
over 119		1				
TOTAL	1402	691	691	92	47	47

OFFICIAL LOAN PERIOD: 14 DAYS

SOURCE: STRATHCLYDE: Undergraduates

DAYS	A	(A)	B	(B)	C	(C)	E	(E)	F	(F)	G	(G)
92-98	3	(2)	4	(2)	1	(1)			2	(2)		
99-105			7	(4)								
106-112	1		3	(3)								
113-119	1		5	(4)								
over 119			4		1		1	(1)	1	(1)		
TOTAL	1696		397		396		154		30		30	
		(691)		(192)		(193)		(67)		(14)		(12)

SOURCE: SUSSEX: Undergraduates

DAYS	A	C	E	G
92-98	6831	323	47	4

OFFICIAL LOAN PERIOD: 28 DAYS

SOURCE: STRATHCLYDE: Staff and Postgraduates

DAYS	A	(A)	B	(B)	C	(C)	E	(E)	F	(F)	G	(G)
0	3	(1)			1	(1)						
1	12	(8)	4	(3)	1	(1)						
2	7	(3)	2	(1)								
3	10	(4)	4	(1)	1							
4	12	(3)	2	(1)								
5	17	(5)										
6	15	(3)	6	(2)								
7	20	(9)	2	(1)								
8	12	(3)	4	(1)	1	(1)						
9	7				1	(1)						
10	8	(2)			1							
11	11	(4)	4	(3)								
12	9	(4)	1	(1)								
13	18	(6)	3	(3)	1							
14	19	(6)	2		2	(1)						
15	15	(5)	2	(1)								
16	10	(6)	2	(1)	3	(1)						
17	18	(9)	2	(1)	3	(1)	3	(2)				
18	17	(12)	2	(2)	3	(2)						
19	13	(10)	2		2	(2)	1					
20	16	(9)	1		3	(2)	1	(1)				
21	19	(8)	3	(2)	3	(2)						

SOURCE: MANCHESTER: Postgraduates

DAYS	A	B	C	E	F	G
0			4			
1		2				
2		10				
3		5				
4		4	2			
5		7				
6		4		1		
7		11	4	1		
8		11			1	
9		5				
10		2	1	1		
11		5		1		
12		6		2		
13		9	1	1		
14		9	3	1		
15		3	2			
16		3				
17		6				
18			1		1	
19		2	1		1	
20		2		2		
21		9	1	1		

SOURCE: MANCHESTER: Staff

DAYS	A	B	C	E	F	G
0			15			
1	5		13			
2	2		15			
3	14		12			
4	1	1	4			
5	1		2			
6	3	2	3			
7	12	6	2			
8	1	3	3			
9	2		10	2	1	
10	2	1	4	2	1	
11	1	3	6			
12	2	2	6			
13	2	1	15			
14	8	3	14		1	
15	2		9			
16		3	2	1	1	
17			15		1	
18	4	4	9			
19	2	2	17			
20	2	3	11			
21	2	3	10		2	

OFFICIAL LOAN PERIOD: 28 DAYS

SOURCE:	STRATHCLYDE: Staff and Postgraduates												MANCHESTER: Postgraduates						Staff						
	A	(A)	B	(B)	C	(C)	E	(E)	F	(F)	G	(G)	A	B	C	E	F	G	A	B	C	E	F	G	
DAYS																									DAYS
22	12	(5)			7	(4)	5	(5)					7	1	3	1		1		4	6				22
23	20	(10)			1		1	(1)			1	(1)	2							3	5			1	23
24	28	(23)	1	(1)	7	(3)	2	(2)					4		2					8	1				24
25	24	(10)			20	(16)					2	(2)	13		2			1		3	1				25
26	33	(20)			12	(4)							7		7				2	4	6			1	26
27	52	(32)			15	(12)	3	(2)					10		14	2		1		3	11		1	1	27
28	133	(76)			70	(49)	3	(3)			4	(2)	22	1	27					15	5			2	28
29	32	(12)	3	(1)	12	(8)	7	(3)			3	(3)	12		4	1			1	1	5			1	29
30	16	(8)			6	(5)	3	(2)					2	1	4	1				4					30
31	20	(11)	2	(2)	3	(2)	1				1	(1)	3		3									1	31
32	14	(8)	1		7	(1)	2	(1)							3			1		4					32
33	14	(6)			5	(3)	1				2			1						3		1			33
34	17	(9)	1		6	(5)	2						1		1	1				9		1		1	34
35	13	(2)	2	(2)	7	(6)	1						2				1			1			1	1	35
36	4	(2)	2		4	(3)	2	(2)							1					2					36
37	1	(1)			1	(1)								1	2					5			1		37
38	6	(1)	2		2				1	(1)										2					38
39	2				1	(1)							1	1						9					39
40			1										1	1						1					40
41	1				1								1	1						4					41
42			2	(2)																6	1				42
43	1				1										1										43
44			1																	1					44
45			1										1	1						5					45
46	1		2	(1)	1				1	(1)			1				1						1		46
47															1					7					47
48			1											2						3					48
49			5	(4)	1				1	(1)				5				1		6					49
50	1	(1)	4	(1)										2			2			2					50
51			2								1														51
52			5											3						1					52
53			5	(5)					1	(1)				1						1		1			53
54			2	(2)	1	(1)							2	4						3					54
55			13	(7)	1	(1)			1				3	10											55
56			22	(15)	1	(1)			3	(2)				9		1				1			1		56
57			1	(1)										3						1					57
58			3	(3)										1						5					58
59			4	(2)	1				1				1	2						3					59
60			3	(2)										1		1				3					60
61	1		2	(1)									1												61
62			2	(2)					1					1									1		62
63	1	(1)	5	(1)																					63

OFFICIAL LOAN PERIOD: 28 DAYS

SOURCE:	STRATHCLYDE: Staff and Postgraduates												MANCHESTER: Postgraduates						MANCHESTER: Staff						
	A	(A)	B	(B)	C	(C)	E	(E)	F	(F)	G	(G)	A	B	C	E	F	G	A	B	C	E	F	G	
DAYS																									DAYS
64														1						2					64
65			1	(1)										3						1					65
66			1	(1)	1	(1)														4					66
67			4	(4)																					67
68			1																	2					68
69			2	(2)							1	(1)		2											69
70			2	(1)																					70
71- 77	1		8	(4)																1					71- 77
78- 84			14	(9)					3	(3)				3						2	1				78- 84
85- 91	1		15	(9)			1		1					6						6		2			85- 91
92- 98	1		15	(2)										2			1			3		1			92- 98
99-105			8	(5)					2	(2)				3						4		1			99-105
106-112	1		5	(5)					2					1						3					106-112
113-119			13	(8)																7					113-119
120-200			19	(11)			1	(1)	1	(1)				18			2			23	1	3			120-200
201-300	1		18	(17)			1		1	(1)										5		4			201-300
301-400			6	(6)																					301-400
401-500			4	(4)																		1			401-500
501-600																				1					501-600
601-700																				1					601-700
701-800			1	(1)																					701-800
801-900			2	(2)																					801-900
TOTAL	740		244		243		62	(37)	20	(13)	20	(13)	212	94	94	20	7	7	73	235	235	10	17	17	TOTAL
			(358)		(148)		(151)																		

OFFICIAL LOAN PERIOD		TOTAL ANALYSED	FREQUENCY OF RENEWAL 0	1	2	3	4	5	6	7	8	9	10 ...	14
7 DAYS														
Manchester:	D	2115	1424	399	142	81	31	17	13	7	1			
Undergraduates	H	140	93	29	11	3	3	0	1					
14 DAYS														
Strathclyde:	D	2096	1700	239	56	46	23	16	9	4	3			
Undergraduates	(D)	(888)	(695)	(97)	(30)	(31)	(13)	(16)	(4)	(1)	(1)			
	H	183	154	16	5	4	1	2	1	1				
	(H)	(81)	(67)	(8)	(1)	(2)	(0)	(1)	(1)	(1)				
Sussex: Under-	D	7154	6831	323	(N.B. Only one renewal permitted)									
graduates	H	51	47	4	(" " " " ")									
28 DAYS														
Strathclyde: Staff	D	993	750	112	50	40	10	16	5	0	3	4		3
and Postgraduates	(D)	(510)	(359)	(63)	(31)	(18)	(9)	(15)	(5)	(0)	(3)	(4)		(3)
	H	83	62	11	6	2	1	1						
	(H)	(50)	(37)	(7)	(3)	(1)	(1)	(1)						
Manchester:	D	307	213	52	19	7	7	7	2					
Postgraduates	H	27	20	4	1	0	2							
Teaching staff	D	306	73	140	37	18	18	12	10	0	0	1		
	H	27	10	3	2	5	3	2	1	0	0	0	1	

TABLE B2: FREQUENCY OF RENEWAL

APPENDIX C: BIBLIOGRAPHY

C.1. PROJECT BIBLIOGRAPHY

The following publications derive from the work carried out during the project.

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UNIVERSITY OF LANCASTER OCCASIONAL PAPERS

1. Some implications for library management of scattering and obsolescence, by M.K. BUCKLAND and I. WOODBURN. May 1968. Reprinted with corrections, August 1968. Out of print. Available through the ERIC Clearing house for Library and Information Sciences as report ED 022 502.
   A photocopy can be supplied for 13s. 6d. plus postage on application to the Librarian.

2. An analytical approach to duplication and availability, by M.K. BUCKLAND and I. WOODBURN. June 1968.
   Out of print. A revised version of this report has appeared in the journal Information Storage and Retrieval vol. 5, 1969, pp 69-79.
   Available through the ERIC Clearing house for Library and Information Sciences as report ED 022 516.
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3. Planning library services: proceeding of a research seminar held at the University of Lancaster 9-11 July 1969. sbn 901699 01 2. edited by A.G. MACKENZIE and I.M. STUART. October, 1969. 30/- post free from the Librarian.

4. Systems analysis of a university library, by M.K. BUCKLAND, A. HINDLE, A.G. MACKENZIE and I. WOODBURN. sbn 901699 02 0. January 1970. 15/- post free from the Librarian.

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